Manufacturing Development Guide September 2001

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Executive Summary

This document is about improvement in business systems and processes. It was initially developed by a joint government/industry team to provide guidance for the improvement of weapon system acquisition. It presents information for implementing systems and practices in defense acquisition programs that will help ensure effective and efficient contract performance. Intended primarily for Air Force acquisition personnel and their contractor counterparts, any organization interested in improving their operations will find help in the topics and guidance presented. The Manufacturing Development Guide is fully compatible with the Defense Department's "Acquisition Reform" and "Lean Aerospace" initiatives.

Affordability has become a primary metric for the weapons acquisition community, and the failure to achieve affordability now ranks as the number one challenge for major weapon system programs. In response to this challenge, numerous initiatives have blossomed under the acquisition reform umbrella. The objective is to make tools and techniques that facilitated the quality revolution in the commercial sector available to defense program customers, contractors, and suppliers.

One of the most important objectives of the MDG ***is integrating manufacturing engineering considerations early in the development phases*** of weapons system acquisitions. The MDG promotes a clear understanding of the significant design and manufacturing decisions to be made early in the development process and the substantial program costs and risks associated with these decisions. The intent is that issues critical to affordability, schedule, and product performance can be balanced. It is in the development stage that manufacturing guidance will have the most impact on the life cycle of the program.

Acquisition Reform recommends extensive changes to the fundamentals of defense acquisition. A problem confronting government program managers today is how best to convey in Requests for Proposals (RFP) the need for contractors to utilize the concepts that are now being successfully applied in today's competitive global economy. It is important to identify proven best practices and concepts and structure programs to implement these concepts. The Manufacturing Development Guide was created specifically to address these issues. It enables management to identify practices that a program should employ to maximize affordability and performance payoffs while achieving quality. It provides executable guidance, phase by phase, across the entire acquisition life cycle. For each practice discussed, the MDG offers flexible, specific language for tailoring and insertion into the government's solicitation package and for incorporation into the contract. The guide's applicability may vary, depending on the program and acquisition process being utilized.

The Manufacturing Development Guide consists of an introduction and six main parts: (1) Acquisition Reform initiatives related to the MDG; (2) Acquisition Strategy elements which are affected by MDG implementation; (3) Manufacturing Engineering's Role in Integrated Product and Process Development (IPPD); (4) Engineering for Affordability & Producibility considerations; (5) Quality systems concepts which emphasize defect prevention; and (6) a set of 12 MDG practices and their application throughout the acquisition life cycle.

The guidance provided in the first 5 chapters is applicable to all acquisitions without regard to contract phases, while guidance related to application of the 12 practices is based on the phase of the applicable acquisition program. Practices related to pre-Engineering and Manufacturing Development (pre-EMD)

phases are discussed in Chapter 7, those related to EMD are discussed in Chapter 8, and post-EMD practices are discussed in Chapter 9.

The practices briefly summarized in the next few paragraphs are developed in greater detail in Chapters 7, 8, and 9:

Manufacturing Capability Assessment and Risk Management

The manufacturing capability assessment and risk management effort is a structured, disciplined approach to evaluating manufacturing capabilities, identifying and assessing risk, and developing risk mitigation plans to maintain an acceptable level of risk. The principle objective is to identify appropriate actions to assure that manufacturing processes mature along with product design so that they will be available to support the production and support acquisition phases.

Key Suppliers

Key suppliers should be integrated into the Integrated Product Teams (IPTs) as early as possible to take full advantage of their product and process knowledge. They should be selected based on a proven ability to perform and on their ability to satisfy program needs.

Key Characteristics and Processes

Key Characteristics are design features whose variation significantly impacts product performance, quality, cost, or safety. The identification of key product characteristics and their design limits, along with the identification of key production processes and their capabilities, are basic engineering tasks, which should be performed in both the pre-EMD and EMD phases. These tasks are intended to support variability reduction and continuous improvement in the EMD and Production phases and to facilitate cost-effective product improvement activities. Key Characteristics provide a unique communication tool, which links requirements, design, manufacturing, and support.

Variability Reduction

Variability reduction is a systematic approach to reducing product and process variability in order to improve cost, schedule and performance. It is based on the concept that just meeting specification limits is not the best measure of quality. Rather, the degree of variability of a key process and its relationship to design limits (process capability) becomes the measure of merit. During Pre-EMD and EMD phases, data collection and process control procedures are established, process capabilities are calculated based upon available data, and feedback is provided to the designers on the ability to meet proposed tolerances. These efforts are essential to assess process capability and stability in preparation for the production decision. Variability reduction efforts during production are primarily concerned with continuous improvement in product quality and manufacturing process efficiency.

Virtual Manufacturing

Virtual Manufacturing is an integrated manufacturing approach which effectively addresses materials, processes, tooling, facilities, and personnel issues involved in a product's design and manufacture *before* the product and process designs are released while changes can be implemented with less cost. A combination of virtual manufacturing and virtual prototyping capabilities enables the IPT to accomplish three important objectives: (1) validate product designs and production processes in a virtual

environment; (2) evaluate the performance characteristics of a variety of product configurations; and (3) make effective cost and performance trades during early development activities.

Production Cost Modeling

The intent of this practice is to provide a Production Cost Model (PCM), which can be used to estimate the projected production cost of the proposed design and compare against a threshold value for affordability. In addition, the PCM will be a critical tool for implementing Cost as an Independent Variable (CAIV). It will be used in the trade studies practice to assess and accumulate design-related costs (associated with the factory).

Design Trade Studies

Design trade studies focus on providing a balanced product design accommodating cost, schedule, and performance criteria. They should include production processes, tooling, test equipment, and support equipment issues. Desired and threshold values are defined for each system performance parameter. Trade studies provide the ability to optimize system design within these values.

Long Lead and Non-Recurring Activities

In today's acquisition environment, long lead items and non-recurring activities are issues to be addressed in the Engineering and Manufacturing Development (EMD) phase of the weapon system program rather than the production phase. One of the key objectives of the new acquisition environment is the incremental demonstration and verification of production process capabilities early by maximizing the use of final production processes, equipment, tooling, and test equipment in the development phase. This and the relocation of LRIP into EMD requires the program to focus much earlier on many issues that were traditionally part of non-recurring activities in the production phase. Identification and reduction of the number of long lead items should be a product of the engineering design process.

Product and Process Validation

The focus of Product and Process Validation is on methods of verifying the capabilities of production equipment and processes. The rapid development of effective virtual manufacturing and virtual assembly tools has provided additional methodologies by which many of the objectives of conventional line proofing can be met. The decision to use line proofing, virtual tools, or some combination of the two to support a particular program will require an analysis of the comparative cost, schedule, and quality impacts.

Product Improvement

Product improvements are introduced to address new performance requirements or to take advantage of new technologies or subsystems that reduce cost or enhance performance. The focus of this practice is to use the MDG concepts discussed above when making product improvements and manufacturing changes. The use of block changes provides a disciplined, cost effective process for introducing and consolidating process changes.

Manufacturing Process Control and Continuous Improvement

During production, the responsibility of the manufacturing engineering function is to focus on the effective control of the manufacturing processes and on the orderly incorporation of improvements in

both product and process. Contracts should be structured to provide incentives for continuous production phase improvements, schedule gains, enhanced affordability, reduced acquisition cost, and enhanced supportability.

Factory Efficiency

Factory efficiency is achieved by the continuous application of all appropriate lean manufacturing practices, high performance manufacturing systems, and continuous improvement practices and principals during production. It extends far beyond the confines of the factory floor to include such issues as risk management and the long-term impact of make-buy decisions on the industrial base.

Manufacturing Development Guide

Chapter 1: INTRODUCTION

1.1 The Purpose of the Manufacturing Development Guide

The purpose of the Manufacturing Development Guide (MDG) is to promote the timely development, production, and fielding of affordable and capable weapon systems by addressing manufacturing and quality issues throughout the program acquisition cycle**.** Its primary focus is to identify and encourage the use of proven manufacturing and quality related technical and business practices to achieve this purpose. Primary customers of the guide are Systems Program Office (SPO) personnel at the Air Force Materiel Command's (AFMC) Aeronautical Systems Center (ASC) and their defense contractors. The MDG emphasizes roles and responsibilities of personnel performing manufacturing engineering tasks in all phases of the acquisition process. It is also applicable to work traditionally performed by systems engineers, quality assurance personnel, program managers, and other personnel whose work with Air Force contracts affects successful development, production, and fielding of affordable and capable weapon systems.

The MDG provides implementation guidance for Department of Defense (DoD) acquisition policy, promotes Integrated Product and Process Development (IPPD) and concurrent engineering policies. It is consistent with the change to a performance based acquisition environment, as well as the use of non-government standards, Single Process Initiatives (SPI), commercial products and practices, improved supplier relations, and other acquisition reform initiatives.

1.2 A Statement of the Problem

In the past, the goal of developing and deploying economically supportable weapon systems capable of meeting all functional user requirements has been proven difficult to achieve. Historically, two basic problems have been experienced to varying degrees by weapon system acquisition programs: (1) Difficulty in developing, producing, and fielding supportable new weapon systems, modifications, and upgrades in a timely and affordable manner; and (2) Difficulty in smoothly transitioning an acquisition program from development to production.

The Timely Fielding of Affordable Systems

Our difficulty in fielding mature systems in a timely and cost effective manner has been a persistent problem experienced to some degree on nearly every program. The symptoms and impacts of these problems vary according to the observer's perspective, but many of the main issues are summarized below:

Acquisition Community

- **Symptoms:** high risk in the transition from development to production, high initial

acquisition costs, and the need for excessive engineering support to stabilize the design and manufacturing processes.

- **Impacts:** increased costs, production schedule slips, and early and frequent engineering changes.

User Community

- **Symptoms:** late deliveries and the inability of the system to meet all requirements, especially in the areas of reliability and supportability.
- **Impacts:** delay in Required Assets Availability (RAA) and reduced operational capability (particularly in sortie generation).

Support Community

- **Symptoms:** high initial repair rates, unexpected failure modes, and excessive configuration changes.
- **Impacts:** increased spares requirements, excessive failure analyses and corrective actions, more complex configuration tracking systems, and numerous technical order changes, resulting in increased costs and the potential inability to maintain adequate operational capabilities.

Transition to Production

Most modern acquisition programs have experienced problems in transitioning from development to production. Symptoms include poor quality and low yields of key manufacturing processes, inability to support production rates using processes used in development, cost increases and schedule delays while production capable processes are being developed. These problems can be linked to (1) the lack of an effective plan for the development and maturity of production processes during the pre-production acquisition phases concurrent with product development; (2) not understanding the linkage between key design requirements, the processes needed to support them, and the impact on product performance, supportability, and cost; and (3) ineffective risk assessment, mitigation, and monitoring activities supporting critical process development.

1.3 Root Cause

A root cause analysis indicates that a major source of these problems is the lack of thorough consideration of the capability and stability of production processes to support production and operation of the weapon system products. This problem can be characterized as follows:

Inadequate response at the start of the program to high production risk:

- Lack of understanding regarding existing process capabilities (process characterization).
- Lack of source selection criteria related to process capability.

- Lack of a long-range production investment strategy as part of the overall acquisition strategy.
- Lack of stable requirements, with a reasonable match between requirements and existing process capabilities.
- Lack of programmatic focus on the need for balanced simultaneous product and process development.

Lack of attention to process capability during development:

- Insufficient or untimely consideration of producibility analyses.
- Product design instability resulting from an emphasis on meeting performance requirements without consideration of producibility.
- Insufficient identification of key product characteristics and key process parameters (product characterization).
- Late initiation of production planning and risk mitigation efforts.
- Lack of exit criteria for key processes and a lack of process related milestones.

Lack of process control in production:

- Lack of process control requirements.
- Lack of identified key product characteristics and/or key process parameters for monitoring and controlling.
- Lack of process improvement efforts.
- Lack of hard cost control requirements or incentives to control / reduce life cycle cost.

Lack of emphasis on process capability for field support/sustainment:

- Failure to address supportability issues and field environment during design.
- Lack of attention to the maturity and future availability of spare parts.
- Lack of attention to required repair procedures.
- Lack of planning and funding for initial support of the fielded product.

1.4 MDG Success Criteria

To achieve the MDG purpose stated earlier, the following success criteria and supporting practices are stressed.

Achieve a balance in the consideration of product and process capability at the start of every phase of the acquisition process by:

- Balanced investments in both product and process during the pre-Production program phases.
- Consideration of process capability in the technology development and technology insertion efforts.
- Incorporation of evaluation criteria for production process capability in source selection with firm requirements for such issues as process development, process validation, process control, and production cost estimation.
- A well-defined production investment strategy as part of the overall acquisition strategy.
- Establishment of capabilities for realistically evaluating the balance of the technical, cost, and schedule aspects of the total system through such techniques as linked cost and performance models and electronic simulation of the manufacturing and support environments.

Achieve a balance of product/process development during each phase of acquisition by:

- Identification of exit criteria for all key events and milestones appropriate to developing, establishing, and validating required process capabilities.
- A dedicated effort to stabilize the product design early in the development program through balanced trades between performance, cost, and schedule, with attention to producibility and supportability.
- Earlier accommodation of production-related issues such as Special Tooling, Special Test Equipment, and Support Equipment (ST/STE/SE) design and fabrication; and use of actual production processes to fabricate, assemble, and test prototype equipment to prove the manufacturing process.
- Modeling and simulation of the design, production, and support environments.

Establish a development and manufacturing environment that implements the practices of key characteristics, process controls, variability reduction, and defect prevention by:

- Requirement flow down practices which identify key product characteristics, key production processes, and key process parameters at all supplier levels.
- Well-defined process control practices identified in the build-to data package.
- Implementation of efficient variability reduction programs which improve dimensional control, yield higher product/process quality and reliability, and create an environment of preventive rather than corrective action.

Consider field support/sustainment process capability and environment during product development by:

- Development of maintenance and repair processes during the product development phase.
- Determining product and process capabilities for spares through identification of key product features and process requirements in the build-to package.
- Adequate planning for support of the product starting with initial deployment.

1.5 Manufacturing Development Guide Technical Content

This Manufacturing Development Guide identifies 12 distinct practices to address the success criteria described above. Their application to Pre-EMD, EMD and Production acquisition phases is discussed in Chapters 7, 8 and 9 respectively. Not all practices are covered in each chapter, but only those most appropriate for that acquisition phase.

Prior to the three chapters that address the acquisition phases and the specific applicable practices, overarching management systems and non-phase specific information of general interest are discussed in Chapters 2, 3, 4, 5, and 6. Each of these chapters is summarized below:

Chapter 2, Acquisition Reform, provides an introduction to concepts which support MDG practices. The discussion covers acquisition reform initiatives such as Integrated Product and Process Development, the Performance Based Business Environment, Cost as an Independent Variable, and the Single Process Initiative.

Chapter 3, Acquisition Strategy, addresses business strategy issues such as program and financial management, program scheduling, cost reporting, and funding necessary to implement the MDG practices. It also contains a special section addressing the Statement of Objective (SOO) philosophy in program acquisition.

Chapter 4, Manufacturing Engineering's Role in IPPD, describes the heightened importance of the manufacturing engineer's mission in the integrated product team environment. The involvement of manufacturing engineering in the product definition process provides for early identification and

mitigation of producibility issues, cost issues, and potential transition-to-production risks.

Chapter 5, Engineering for Affordability & Producibility, addresses how weapon system costs, both flyaway and life cycle, must be treated as system requirements equal in importance to quality, reliability, and technical performance. This section describes dedicated producibility, affordability, and value engineering programs.

Chapter 6, Quality Systems, addresses the correlation between the tools and techniques contained in this guide and concepts that many companies have implemented as part of their modern Quality Systems. Both emphasize the importance of quality in the development process to achieve producible designs; quality in the design of capable, controlled manufacturing processes; and quality through the prevention of defects rather than after-the-fact detection of defects.

1.6 Intended Use of MDG

The objective of this document is to provide a technical understanding of the practices presented, along with guidance on including, where appropriate, these concepts in the RFP and contract, and assessing their implementation success throughout the acquisition process. Recommended RFP and contract language is provided in chapters 4, 5, and 6, and for each practice in chapters 7, 8, and 9. The guide includes sample language for Statement of Work (SOW), Integrated Master Plan (IMP) exit criteria, Contract Data Requirements List (CDRL), Proposal Instructions to Offerors (Section L), and Evaluation Criteria Guidance (Section M). In addition, sample Statement of Objective (SOO) language is provided in the introductions to the acquisition phase chapters and in the Quality System section, Chapter 6, to convey the government's expectations for manufacturing and quality during the acquisition process. Finally, the MDG recommends that an Average Unit Production Price (AUPP) requirement be included in the System Specification to emphasize affordability and the concept of Cost As an Independent Variable (CAIV). Example specification language for this requirement is included in Engineering For Affordability, Chapter 5.

1.7 The Relationships Among Practices

Many of these practices rely on receiving input from others to achieve the largest return on investment. For example, the Production Cost Modeling practice in EMD benefits from well-executed practices covered in the MDG sections on Manufacturing Engineering's Role in IPPD, Engineering for Affordability, and Virtual Manufacturing during pre-EMD activities.

It is an objective of the MDG that all appropriate practices be implemented systematically in an Integrated Product Team environment with all stakeholders involved. These practices may be less effective when implemented in a discrete or sequential fashion.

1.8 Benefits

MDG practices, like many aspects of acquisition reform, represent a significant change in the way the defense industry operates. Achieving the full range of benefits available from the MDG practices will require basic cultural changes on the part of all parties involved, from users through low-tier suppliers. Some of the practices will require an up-front investment of material and/or labor during early development, with returns not realized until later in EMD and Production. The commitment to make these up-front investments and continue the MDG practice activities throughout the life of the program is essential. The benefits resulting from implementation of MDG practices include:

- Shorter development schedules and reduced cycle times.
- Better first article quality.
- Development of robust product designs.
- Easier transition of designs to production.
- Better supplier product integration.
- Quicker resolution of problems.
- More effective risk management.

These benefits have been shown to be achievable by a number of studies and through actual experience on a variety of programs. Implementation of the concepts described in this guide begins with top leadership commitment and must be flowed throughout the program organization. It is also imperative that the tools, techniques, and systems the MDG promotes be tailored to the individual program. The suggested RFP and contractual language referenced in chapters 4 through 9 has been formatted with this in mind.

Manufacturing Development Guide

Chapter 2: ACQUISITION REFORM

2.1 Introduction

DoD directives removed most of the proscriptive specifications and standards that had governed procurement practices for the past several decades. The acquisition community is now implementing performance-based specifications and standards, non-governmental and commercial standards, single process initiatives, block contract changes, and a number of other tools and initiatives that have been shown to positively impact affordability. The MDG is not an acquisition reform initiative but is consistent with current directives and supports their objectives.

2.2 Features of Acquisition Reform

Just as the quality revolution changed the consumer market place, acquisition reform is changing the defense marketplace. Major features of this environment related to the MDG include:

- A new emphasis on system affordability and acquisition of best value products.
- Performance based requirements and specifications that are incrementally verified throughout development.
- A formal program of risk identification and management in the areas of performance, affordability, and schedule.
- Contractor control of the development, design, and configuration to the maximum extent feasible.
- The maximum use of contractor processes and facilities.
- Enhanced opportunities for the incorporation of advanced technologies.
- Expanded use of modeling and simulation for both product performance and product manufacturing.
- Transitioning from an emphasis on government oversight to government insight.

2.3 Essential Conditions for MDG Success

To realize the full benefits from the MDG the following features of the acquisition environment must be

present:

- Implementation flexibility is critical if the increased contractor and government efficiencies available through performance-based acquisition are to be realized.
- Performance based specifications must incorporate the essential performance attributes formerly contained in documents such as the Statement of Work (SOW) and MIL Standards and Specifications.
- A common technical database must support all system design, fabrication, and support requirements, including engineering design, tooling, test and support equipment, and technical orders.
- Effective flow-down of PBBE requirements and principles to the lowest level of the supplier chain is essential to permit intelligent, flexible tailoring of the requirements, and to allow suppliers to use their processes effectively so that product integrity is assured.
- A performance based product description data package must capture not only the development specification and build-to information, but also design intent and requirements allocations.

2.4 Acquisition Reform Initiatives Supporting MDG

Acquisition Reform covers numerous functional aspects of the acquisition process, while the MDG focuses on manufacturing and industrial engineering practices supporting the development and production of a weapon system. The MDG does support, and is supported by, acquisition reform. Discussed below are several acquisition reform initiatives that relate to, and support, MDG practices and guidance.

Teamwork

One of the major goals of the MDG (and acquisition reform in general) is to make the government an active participant in the prime contractor's day-to-day program activities through membership on the contractor's Integrated Product Teams. One direct benefit of this increased government participation is a minimized number of formal Contract Data Requirements and reviews. The goal is for the government to maintain insight into the significant daily activities of the program instead of through oversight via formal reviews and deliverables.

Integrated Product and Process Development

Integrated Product and Process Development (IPPD) and Integrated Product Teams (IPTs) represent a cultural foundation that is essential for successful implementation of the practices described in the Manufacturing Development Guide. IPPD is a DoD term for the implementation of concurrent engineering methods. IPPD is a philosophy that promotes teaming of functional disciplines to integrate and concurrently apply all necessary processes to produce a product that satisfies customer needs. IPTs, in turn, represent a management approach for accomplishing IPPD. An IPT is a team formed for the

purpose of delivering a specific product or managing a specific process. IPTs bring together all the functions that have a stake in the product or process. The members of the IPT concurrently consider all issues affecting the design, development, and production of the product.

Operational Safety, Suitability & Effectiveness (OSS&E)

Air Force Policy Directive 63-12 assigns Single Managers the responsibility to ensure and preserve the operational safety, suitability, and effectiveness of their weapon systems. Air Force Instruction (AFI) 63-1201 describes mandatory acquisition process elements required to assure OSS&E. Elements within AFI 63-1201 impacted by MDG principles and practices include:

- Use of a disciplined engineering process
- Evaluation of Total Ownership Costs (TOC)
- Ability of maintenance and repair sources to deliver quality products
- Capability of supply sources to produce parts and supplies that preserve OSS&E

Many of the MDG practices support the achievement of these process elements:

- Identification of Key Characteristics -- plays a critical role in maintaining a disciplined engineering process by guiding design engineers through an analysis of the most critical product characteristics.
- Production Cost Modeling -- should be used to develop, understand, and evaluate Total Ownership Costs and the impacts of design and management decisions on TOC
- Manufacturing Process Capability Assessment -- facilitates the matching of key characteristics with process capabilities to ensure the production and delivery of quality products that preserve OSS&E.
- Quality Management Systems -- must be implemented to assure the as-delivered products meet the as-designed configuration.
- Key suppliers -- suppliers must have sufficient capability to meet design requirements and be evaluated to assure they have effective quality programs in place.

Cost as an Independent Variable

Another key consideration of the performance based business environment is the issue of Cost as an Independent Variable (CAIV). CAIV is intended to focus acquisition efforts much more rigorously on tradeoffs between cost and the desired features and performance characteristics of the weapon system. One result is that cost estimating tools will need to be used early in the conceptual phase of a program.

In an analysis of CAIV issues presented to the American Society of Naval Engineers[1], the impact of CAIV is assessed as a fundamental one. The need to make cost a higher priority will necessitate a shift from the traditional requirement setting process, and will necessitate some important procedural changes in cost estimating, the report concludes. These procedural changes will include a streamlining of the

mechanism of costing, a shift in the choice of variables, a mathematical reversal of the process, and better top-level descriptive equations and graphics that portray total costs as a function of operational and technical parameters.

Single Process Initiative (SPI)

The Single Process Initiative allows the contractor to request a change to common, facility-wide processes in lieu of contract unique processes. Use of common processes is intended to reduce contractor operating costs and achieve cost, schedule, and performance benefits for the government. The Administrative Contracting Officers (ACOs) coordinate and negotiate class contract modifications (Block Changes) to existing contracts for contractor single process proposals. The contractor must propose the scope of and technically substantiate common process proposals.

Specifications and Standards

To meet future needs, the Department of Defense must increase access to commercial state-of-the-art technology and must facilitate supplier adoption of business processes characteristic of world-class suppliers. In addition, integration of commercial and military development and manufacturing facilitates the development of dual-use processes and products and contributes to an expanded industrial base capable of meeting defense needs at lower costs.

To accomplish this objective, the Deputy Under Secretary of Defense (Acquisition Reform) directed the use of performance and commercial specifications and standards in lieu of military specifications and standards unless no practical alternative exists to meet the user's needs. Performance specifications communicate the user's requirements to the supplier. They translate operational requirements into more technical language that provides the manufacturer with two very important parameters: (1) What to consider as an acceptable product -- stated in product performance terms, and (2) How the government will determine if the product is acceptable.

Performance Based Business Environment (PBBE)

The Joint Aeronautical Commanders Group (JACG), which was formed by the Joint Logistics Commanders, coined the term PBBE. This concept defines an environment that implements the objectives of acquisition reform and provides guidance on the acquisition of aeronautical weapon systems. PBBE products include documents covering risk management, flexible sustainment, performance-based product definition, joint service specification guides, key supplier processes, and contractor performance. Manufacturing and quality personnel must become familiar with PBBE concepts and consider them in conjunction with MDG practices when supporting acquisitions at the Aeronautical Systems Center.

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[1] *Cost as an Independent Variable (CAIV): A Framework and a Tool Set for Costing in a CAIV Environment*, Richard L. Coleman, TASC, Inc., and Dineen O. Manarelli, OUSD (A&T), S&TS, NW. (A 1996 paper submitted to the American Society of Navel Engineers)

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Chapter 3: ACQUISITION STRATEGY

3.1 Introduction

The acquisition strategy developed for each program should address the need to promote producibility and affordability as high priorities. The MDG production engineering and producibility efforts start at Milestone I, continue through the Production phase, and extend into product support.

The MDG approach moves tasks such as development of production tooling, planning, and manufacturing processes forward into the developmental phases. The traditional funding profile must likewise shift, pulling some traditional Production Phase funding into EMD and pre-EMD phases.

This chapter addresses a variety of contracting and source selection concepts that will be instrumental in identifying appropriate MDG practices to implement and in choosing contractors who are capable of delivering the technical effort required.

3.2 Program Management Considerations

This chapter of the Manufacturing Development Guide provides information on the proper management structures for implementing a program's manufacturing and quality technical requirements. Included are guidelines on developing viable program schedules, minimizing contractual calendar milestones, getting user commitment on production quantities, and effecting RFP process changes.

Schedule Development Activities.

Traditionally, schedule development activities have begun well before the Draft RFP is released, and continue throughout the program's life. The form of these schedules may change, but fundamentally they identify tasks to be accomplished, the interdependencies of tasks and their linkage to milestones, and a calendar association for each task showing its start and completion. In today's environment, this schedule takes the form of the Integrated Master Plan (IMP) and Integrated Master Schedule (IMS).

Integrated Master Plan (IMP) - an event-driven plan that documents the significant accomplishments necessary to complete the work defined in the SOW and tie the accomplishment to a key program event.

Integrated Master Schedule (IMS) - a schedule to plan the accomplishments defined in the IMP; may also provide more detail and insight into the completion of an accomplishment.

The IMP/IMS will integrate all of the unique aspects of the program and serve as a single management tool to monitor work progression toward the accomplishment of program goals and objectives. It is critical that MDG tasks be identified in the IMP, along with exit criteria which define successful completion of the task. The IMP then relates these MDG activities to program milestones and

schedules. This is of particular importance because of the increase in technical requirements in support of the MDG. An increased emphasis on schedule development is required to effectively implement the MDG. To ensure the greatest effectiveness, scheduling must begin well before the draft RFP phase begins.

The program IPT must develop the initial schedule. Typically, the SPO's program control personnel, in conjunction with other functions, develop the schedule. Once the initial schedule has been developed, it should be modified to reflect the inputs of prospective contractors, solicited during the draft RFP stage. The goal is to develop an integrated schedule that considers all contractor inputs. Updates can be made during source selection.

At source selection, the RFP should ensure that adequate data is requested to accomplish a Schedule Risk Assessment (SRA) for each offeror. An SRA will be conducted on each offeror's proposed schedule at source selection. The SRA will incorporate all of the contractor's proposed changes to the program schedule (which are usually minimal) and will also incorporate the risks inherent in each proposal.

Once a winning contractor has been selected, the appropriate IPT personnel can monitor the schedule. Periodic SRAs are recommended to determine current schedule status and identify needed updates.

Minimizing Contractual Calendar Milestones

To ensure that the proper contractual structure exists for effective implementation of MDG, the program manager should establish only the minimal contract milestones necessary to manage manufacturing risks. One example of an appropriate milestone, for instance, might be the criteria for process verification as part of System Verification Review. Minimization of milestones is due, in part, to acquisition reform and the emphasis on integrated product teams, a partnership relationship between the contractor and government, and reduced delivery of official data items. As a partner in the development process, program office personnel will have insight into development activities, data, and status. Milestones of the past are now accomplished incrementally as an ongoing process. This reduces emphasis on formal reviews, approvals, and contract changes, along with reducing administrative overhead associated with these actions. In addition, it ensures that contractual milestone adjustments and formal contract changes resulting from a dynamic development environment are minimized.

Production Rates and Quantity Ranges.

Another key element of integrated product and process development is an understanding of the rates to be achieved during production. Production rates can drive the type of processes to be used, since different processes are more efficient at different production rates. The process that is most efficient at a rate of 100 units a year may not be efficient at rates of 10 a year or 1,000 a year. It is important that the government recognize that a variety of key program estimates and assumptions (as well as tradeoffs and production cost models) are based on a specified production quantity that is achievable and sustainable. While it is out of the program manager's control to influence Congressional action on quantities, an up-front commitment to a planning quantity is necessary. Since Congress and threat changes may influence quantities, perhaps the best commitment attainable is a range of quantities. This range is just as important as a point estimate of the quantities per year. In the RFP, the offerors should base their proposal on a specific quantity with explanations of how their proposal would change with variations to the proposed quantity.

Technical Data Package

In the Performance Based Business Environment, the technical data package is actually a three-category performance based product description developed by the contractor. As explained in the Joint Aeronautical Commanders' Group (JACG) document, Performance Based Product Definition Guide, "Category 1, *the Product Performance Requirements Development Definition*, defines end item functionality and performance. The information in this category is the result of the translation of operational needs into specific performance requirements for the product or system specified in terms relevant to those who will design and product the product..." It links the operational and engineering environments, establishes the performance requirements to be met by the design effort, and translates them into technical performance language. Category 2, *the Product Design Definition*, represents a significant departure from traditional DoD practice. As stated in the JACG guide, it "defines those elements of the proposed design solution which are critical to achieving the performance requirements defined in Category 1. Consistent with advanced commercial quality practices, it defines key product characteristics, product acceptance criteria, and interface characteristics. Category 3, the *Product Fabrication/Manufacturing Definition*, "specifies the design solution of the qualified end item." It provides a product build package with detailed drawings, bills of material, and production processes requirements and standards.

Decisions on who controls which portions of the technical data package at each level of the specification tree must be driven by program and technical risk, contractor and subcontractor capabilities, affordability issues, and business strategies. Contractors exhibiting greater capabilities for self-governance will be allowed greater authority and responsibility.

Non-Developmental or Commercial Products

While the main focus of the MDG is on development issues, the use of non-developmental items (NDI) or commercial off-the-shelf (COTS) products and processes will certainly increase in the lean acquisition environment that will characterize future weapon system procurement. Appropriate processes will therefore need to be developed to assure the effective integration of these products into programs, and to assure their availability, performance, supportability, and cost effectiveness. With respect to cost, projections indicate that the judicious use of COTS products will serve to reduce program costs. Acquiring components for systems from commercial vendors can provide cost, schedule, and technical benefits making market research knowledge in product specialties increasingly important.

3.3 Financial Considerations

Two financial issues are associated with implementation of the approaches recommended in this guide. The first is a change in development funding profiles to support doing the right tasks at the right times. The second is recognizing the favorable impact that well-timed applications of these techniques will have on reducing the costs of design iterations in the later stages of EMD and ultimately reducing unit production cost. These considerations are reflected in different ways in each phase of a program, as described in the following subsections.

Funding Requirements for Pre-EMD, EMD, and Production

Perhaps the most important business issue related to implementation of the MDG is how to properly

fund programs with these new requirements. In practice, implementation of the MDG will produce significantly different funding profiles than those experienced on past programs, as Figure 3-1 illustrates. To provide an accurate comparison, the projection in the figure assumes that LRIP is conducted in EMD for both funding curves. In actuality, the MDG approach puts LRIP into EMD for new programs, while traditionally LRIP often occurs in Production.

In comparison to historical programs, those programs which incorporate MDG principles may require earlier funding, but the benefits of this earlier investment will greatly reduce life cycle costs, including non-recurring production costs, through the substantial elimination of errors and change orders later in the program.

The MDG suggests that manufacturing processes be proven prior to the start of production and that there be early involvement of the manufacturing engineering discipline in the design process. As a result, inefficiencies in the manufacture of initial production units promise to be fewer and the producibility of the initial design should be improved over that of historical programs. A number of other factors associated with MDG-influenced EMD activity will create a more efficient production environment, reduce the cost of the first production unit, lower the cost improvement curve, and speed up the movement toward standard hour content. Taken together, these kinds of production efficiencies will more than offset any additional early development costs.

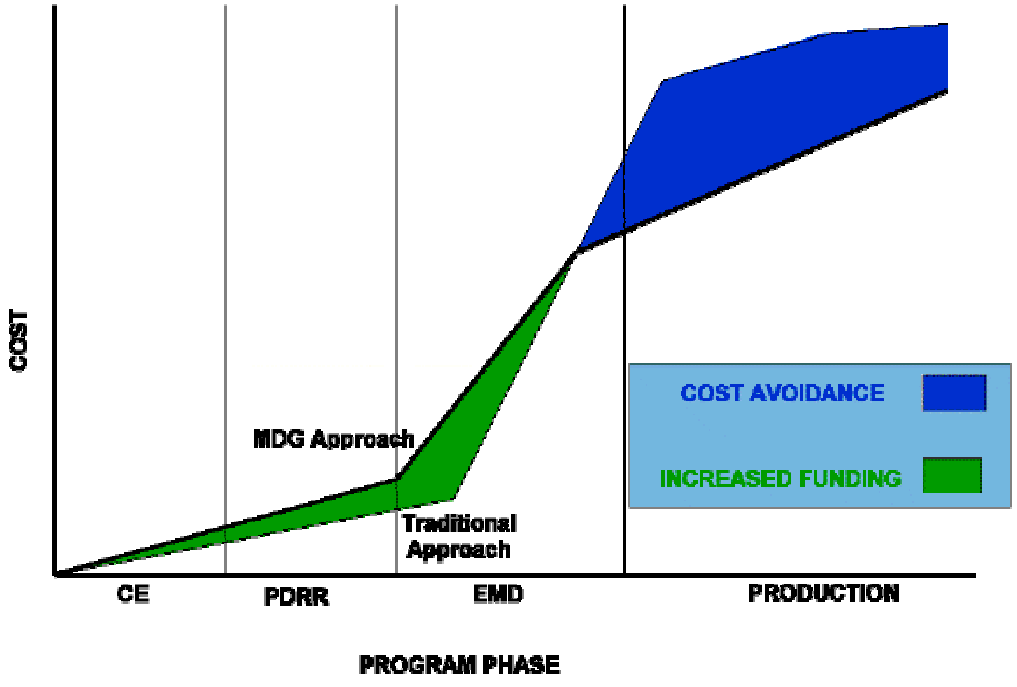

Figure 3-1. A Comparison of MDG and Traditional Program Funding Profiles

The Impact of MDG on the EMD Funding Profile

An example of the impact of implementing MDG practices on program funding profiles during EMD is shown in Figure 3-2. The figure displays the percentage of funds expended for major EMD milestones (PDR, CDR, First Flight), at 12 and 24 months after the First Flight, and at EMD completion. The lower

curve in this figure (labeled "Traditional") represents the average EMD expenditure profile for four historical programs: F-14, F-15, F-16, and F-18A/B. As the figure shows, at first flight these programs had, on average, expended about 50% of their development funding.

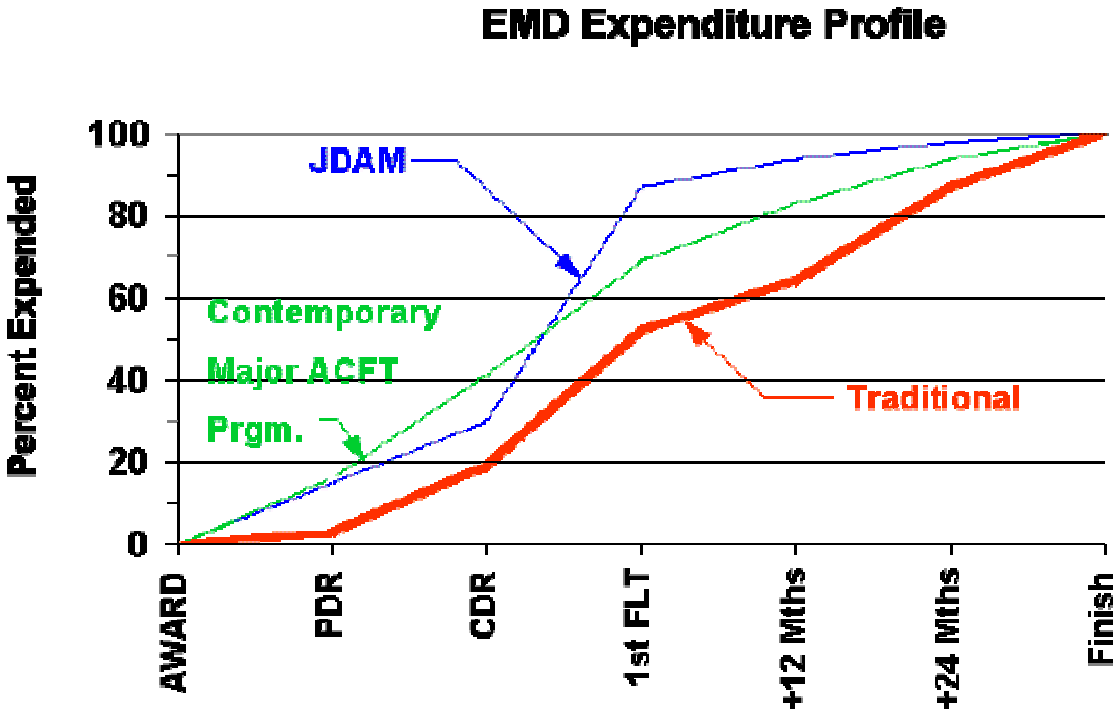

Figure 3-2. EMD Funding Profile Comparisons

For comparison purposes the expenditure profiles for two current programs, F-22 and JDAM, are shown. These programs represent both ends of the acquisition spectrum, from a large, high technology aircraft development program to a multi-service munitions effort. Both of these programs were in EMD during the fall of 1996, JDAM near completion and F-22 prior to first flight. The curves are based on actual expenditures through October 1996 and projections for the remainder of the EMD effort. Both of these programs have been affected by acquisition reform and have implemented many MDG concepts and practices, such as Integrated Product and Process Development (IPPD) and concurrent engineering principles; better integration of suppliers early in the development process; Key Characteristics, and Variability Reduction. The expenditure curves illustrate that MDG concepts have started to significantly affect the phasing of EMD funds. Approximately 70 to 85 percent of EMD funding has been expended by first flight, compared to 50 percent for the historical programs.

This reflects implementation of MDG approaches and requires that efforts usually accomplished late in EMD be moved forward. Certain production phase efforts such as Low Rate Initial Production (LRIP) must also be accomplished during EMD. The expenditure profile on current programs is thus more front-end loaded. Although a single contract may be used for both development and for long lead/non-recurring production items, different types of funding will still be used for each (that is, development funding and production funding).

MDG Cost Estimating Considerations

Pre-EMD Phase - Cost estimating considerations for pre-EMD activities center on the participation of Manufacturing Engineering and Quality Engineering on the IPTs to provide the requirements/cost/ producibility trades which are essential to the new acquisition process. The result is a new set of scope of work issues as measured against traditional program profiles. The typically modest cost of this new scope is offset by reductions in total design cycle time and the enhanced productivity of the new engineering analysis tools. For instance, one defense contractor estimates that as a rule of thumb, one production operations person needs to be added for every ten design engineers to accommodate the new scope of work, but the cost associated with such a move will be more than recouped by later cost avoidance. The intent is for the pre-EMD effort to produce prototypes with product design features that are economically producible. The prototype then becomes the baseline, with incremental verifications and validations of the design provided by pre-EMD modeling and simulations.

EMD Phase - Cost estimating considerations for the EMD phase must now consider the effects of the movement of traditional LRIP activities to EMD and the additional activity required in EMD. The MDG promotes a number of acquisition approaches that require greater effort up front. It can be assumed that EMD will shift labor hours in engineering and tooling to an earlier point in the program as we integrate the design and manufacturing efforts earlier in the program. Leading defense contractors are reporting that design changes can often be reduced by 50% or more. On the F-15 program it's been estimated MDG-related practices would have reduced tooling costs by 40%.

The MDG also recommends the involvement of suppliers early in the design process. It is probable that this requirement will necessitate additional costs in the Material/Subcontract area in EMD. While the total number of suppliers will not increase, the amount of their non-recurring cost will, since they will be brought into the program team to assist in the design phase. The amount of this increase would depend on the number of suppliers involved and how early in the process their involvement begins. We should also expect supplier related design changes to decrease (with a corresponding decrease in costs) because of earlier supplier involvement in the design process.

Product and Process Validation is another concept advocated by the MDG. In the past, if done at all, conventional line proofing most often occurred in LRIP. Under the MDG, it would ideally take place in EMD, since LRIP experience must be acquired in EMD. However, the ability to detect product design errors and tooling errors in a virtual environment in Pre-EMD (as well as EMD), along with process of incremental verification and validation, will reduce the necessity for or the extent of conventional line proofing needed. They should also reduce the need for correction of errors in released design packages, including SE/STE.

The magnitude of cost changes in EMD is dependent on the amount of MDG related effort incorporated into each program. Since the technical requirements are tailorable, each program should have content differences. The cost analyst or estimator should consult with the IPT to ascertain the extent of MDG compliance. However, it is anticipated that EMD would be the cost break-even point for programs aggressively applying MDG tools and practices.

Production Phase - Production phase costs and cost estimating will also be affected by the MDG initiatives. The MDG-influenced up-front investment in EMD concepts should continue to produce

significant cost payoff in Production. Initial cost projections on the JSF Technology Demonstration Program showed unit production cost avoidance due to MDG implementation to be 20% to 30% of the affected hardware budget.[1] Since some traditional LRIP activities will now be accomplished in EMD, production costs must also be adjusted to account for them.

Contractors are now experiencing significant decreases in costs on first units of redesigned product where the IPT processes and virtual manufacturing approaches have been employed. "The impact of an integrated suite of manufacturing simulation tools on seven key metrics has been estimated by engineers currently working on the F-22 advanced fighter project. When the savings are projected onto the Joint Strike program, the SAVE system is estimated to save $3 billion in life cycle cost." [1] Specific areas of increased production efficiency that can be expected from the use of MDG strategies are described in the following paragraphs.

First, redesign of the system should be significantly reduced. Traditionally, systems and processes have been designed in EMD, with changes then made late in EMD and early in production. This design rework commonly designated in historical cost data as recurring and non-recurring production engineering (rather than systems engineering) and tooling should be significantly reduced. In many cases this is due directly to the efforts of the production operations members of the IPT.

Second, with design and manufacturing processes better integrated with manufacturing, the amount of scrap, rework, and repair traditionally associated with manufacturing will be reduced.

Third, since major subcontractors have been involved in the design process, integration of their components into the system should be more efficient. This should be reflected in labor hour savings for all major functional disciplines and more beneficial cost improvement curves. It should also be reflected in fewer engineering changes related to supplier activity.

Fourth, manufacturing labor should start at a lower first unit or T1 cost and proceed down a cost improvement curve that parallels and is below the historical non-MDG curve. Better integration of the design and manufacturing process should bring about a less costly first unit. Traditionally, first unit costs have been high because of the significant amount of manufacturing and re-manufacturing needed to incorporate producibility design changes. This, coupled with the inefficiency of incorporating these changes late in the process, caused high T1 costs and steep cost improvement curves. MDG should create lower first unit production costs and improve efficiency by moving both prime contractor and subcontractor labor to a flatter portion of the cost curve.

Figures 3-3 and 3-4 provide projections of the impact of advanced new design and analysis tools and new manufacturing engineering processes (specifically, virtual prototyping) in an IPPD environment. Both staffing profiles and unit cost curves exhibit significant savings and shortened development cycle times over earlier programs (the learning curve slope in combination with the lower initial unit cost is based on actual defense contractor experience -- the specific source is proprietary). One reason for the projected savings is that Virtual Manufacturing on a fully three-dimensional Computer Aided Design (CAD) product definition can facilitate identification of structural interference prior to release of the drawings. As such, the need for nearly all physical mock-up and shipside engineering can be eliminated.

Fifth, the performance based approach to acquisition provides significant savings through the development and use of defect prevention techniques. Acquisition reform initiatives allow contractors

to adhere to one company-wide quality standard, support the integration of commercial and military efforts, encourage variability reduction, reduce compliance with prescriptive "how to" requirements, and focus more directly on meeting performance requirements. These changes will have a positive effect on both overhead and direct costs.

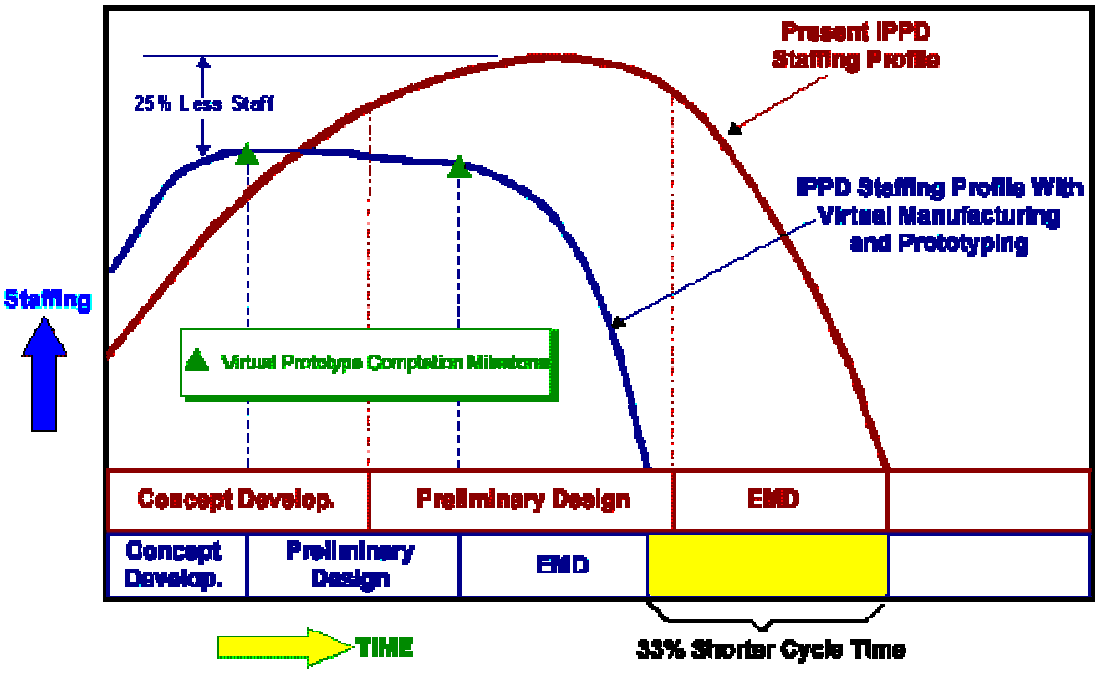

Figure 3-3. The Impact of Virtual Manufacturing in an IPPD Environment

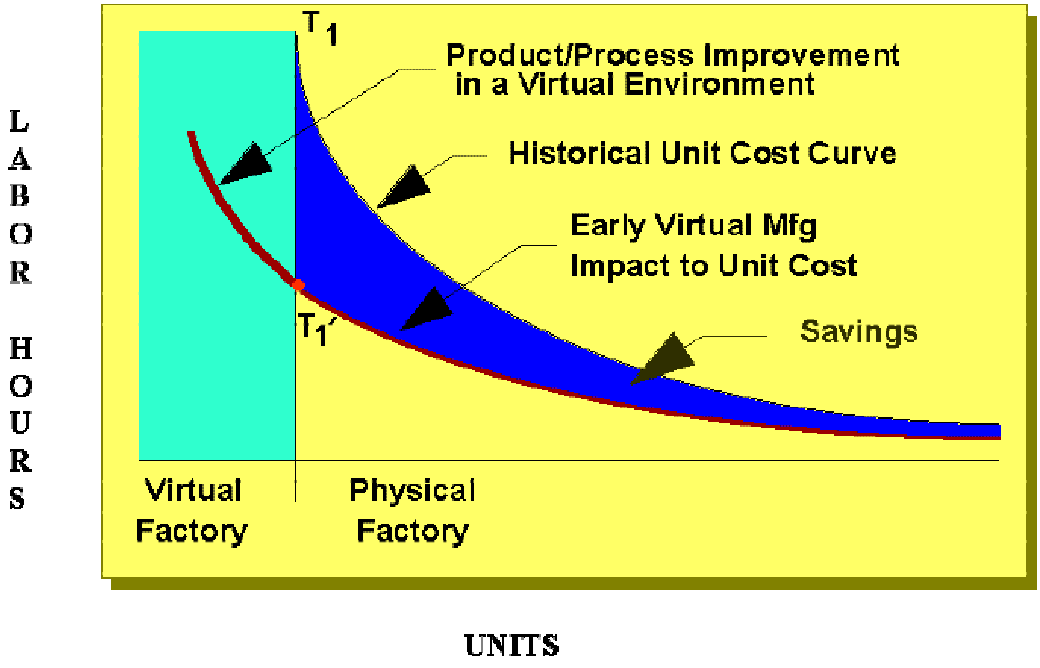

Figure 3-4 Product/Process Improvement in a Virtual Factory Environment.

3.4 Contracting

This section discusses a variety of proposal and contracting issues associated with the implementation of MDG practices and concepts. It is intended to provide insight and guidance for manufacturing and quality personnel supporting these processes.

Contractual Implementation of Requirements

The major thrust of the acquisition reform initiatives has been to institutionalize the following changes:

1. Express RFPs and contracts in the form of performance based requirements, with the government no longer dictating engineering solutions or specifying how problems are to be solved.

2. Give contractors more control of the design, the configuration, and their own technical, management, and business processes.

3. Select high quality contractors to provide DoD products and services.

The major objective in this changed approach is to give contractors maximum flexibility in proposing and executing innovative and affordable approaches to fulfilling DoD program requirements.

Contractual Coverage for Quantity-Based Recoupment

The proper understanding of maximum production rates is another important aspect of the MDG. The most effective design of both a product and its related processes can often be driven by the quantity to be manufactured. Historically, the government has been unable to successfully predict long range (or even short range) production quantities due to threat changes, budget constraints, and Congressional adjustments to programs. Programs may even go "on-the-shelf" at the completion of development. As previously discussed, it has been posited that implementation of MDG practices will provide a payback of the necessary up-front investments prior to production. Some contractors will be concerned about making the needed investments without a commitment for a minimum quantity. In addition, the greater the quantities, the more the investments will pay off. Contractors may require protection for having implemented MDG practices that necessitate contractor investments associated with quantity issues if there is a potential that the program will not progress to the production phase, or where production quantities may be significantly altered.

For instance, a contractor may capitalize special tooling and special test equipment based on a predicted production rate that does not materialize. The program management team should consider some type of compensation arrangement to allow the contractor to recoup all or some of his investment, depending on whether he has multiple customers for the product. One way of accomplishing this is to include a quantity-based recoupment clause in the contract at time of award. It is important to note that this recoupment is a potential contingent liability for which funds must be committed within the program's current available funding. Caution must be taken to avoid potential Anti-Deficiency Act or Cost Accounting Standards violations. It should also be noted that command level or higher approval or coordination might be necessary. Another approach to this problem is to specifically negotiate ahead of

time for the acquisition of Special Tooling and Special Test Equipment on fixed price type contracts, where the Special Tooling and Special Test Equipment would become government property at the end of the contract.

Contractual Incentives for MDG Practices

MDG implementation may be a disincentive for some contractors if its effect is to reduce overall acquisition cost and thereby reduce contractor profit on a cost contract. Some contractors may desire a contractual incentive or contractual funding to perform certain MDG practices (such as variability reduction activities). Others will perform these MDG recommended initiatives as a natural part of their systems engineering process. It is suggested that contractors be encouraged to view MDG practices as part of their general business strategies. Until these practices become a natural part of contractor cultures carefully worded contractual incentives may be appropriate.

Incentives may include: negotiation of target price curves (price targets for multiple lots that assume the use of some MDG concepts, but allow the contractor a share in the savings if the costs are below the curve); award fees (to motivate improvements and best practices on existing contracts); a Value Engineering Program (allowing sharing of savings); and multi-year contracts (a longer-term commitment on the part of the government to encourage long-term contractor investment.)

Draft Request for Proposal Considerations.

As the Draft Request For Proposal (DRFP) is generated; there should be early industry involvement before it is finalized. DRFP discussions will enable the SPO to gain insight from potential offerors on which requirements could cause problems, where cost savings may accrue, and what changes might result in a more executable program. The language and requirements in this handbook are tailorable so DRFP discussions should address and identify applicable MDG features. The following are some of the items that should be discussed with potential offerors.

Performance Objectives Discussions - Offerors should be afforded the opportunity to discuss requirements with user representatives. Specifically, the user should be prepared to address the importance of each requirement, the importance of each "desired" capability, and the potential for productive trades.

Cost Impacts of Changes in Performance Objectives - Offerors should be encouraged to provide the estimated cost impacts of changes in contract product performance objectives. The SPO could then optimize its performance objectives, pursue productive trades for "desired" capabilities, or use the money saved for enhanced capabilities elsewhere. Often a number of requirements can feasibly be relaxed, changed, or eliminated.

Non-Developmental or Commercial Products/Processes - As required by FAR Part 12, market research should be conducted to determine if commercial items are capable of meeting program needs. However, numerous government requirements can restrict the use of commercial items. The DRFP discussions should address whether prime contractors plan to use commercial vendors for components and which, if any, contractual requirements inhibit the effective use of commercial items.

Cost Impacts of Contract Requirements - Controlling costs is of major importance on all programs, especially EMD programs where the contract type may be cost reimbursable. Therefore, DRFP discussions should also include a review of any program-peculiar requirements that increase

direct costs and/or overhead. Often the government will unknowingly require contractors to accomplish work that is paid out of overhead accounts. Allowing prospective contractors to review the DRFP for impacts to overhead should lessen the chances of government requirements driving up these costs.

RFP Philosophy

In the new acquisition environment, the user community establishes the top-level performance requirements in an ORD. The acquisition community, sometimes in conjunction with the user and a contractor, develop a performance specification to meet those requirements. To develop a RFP around these requirements, the acquiring SPO first conducts a risk analysis of the requirements to identify the risk of achieving each requirement within program budget and schedule constraints. For manufacturing, the risks may revolve around requirements that push the state-of-the-art in manufacturing technology. The product's performance requirements, acquisition strategy, and acquisition phase may also drive risks. Once risks are identified, their probability of occurrence must be estimated as well as their potential impact to the program.

For risks that may have unacceptable probabilities and/or consequences, objectives for overcoming these risks are written and collected into a Statement of Objectives (SOO). Examples of SOO wording as they relate to manufacturing objectives are contained in subsequent chapters of the MDG. These objectives are then translated into evaluation criteria (section M) which will be used to evaluate how well the offerors' approaches will reduce the risks. From these criteria, the section L (Instructions to Offerors) is written to tell the offerors what to discuss in their proposal. The bottom line is that the RFP should be built around risks, not "pet rocks" or preferred practices. Many of the MDG principles and practices should be used to reduce risks as opposed to being applied indiscriminately.

The contractor responds to the SOO and specification with a Statement of Work (SOW) that defines the tasks and the performance capabilities that will result from those tasks. The Manufacturing Development Guide SOW guidelines (included in subsequent chapters) provide the prime contractor with information on what is viewed as important for inclusion in the SOW from a manufacturing development perspective. Appropriate portions of the contractor's SOW are incorporated into the contractual document to define the work to be performed and the resulting product performance. The SOO and specification thus provide input to a template for evaluating the contractor's SOW.

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[1] Simulation Assessment Validation Environment (SAVE) Report, Lockheed Martin and The Air Force Research Laboratory, Manufacturing Technology Division, 28 January 1998

Manufacturing Development Guide

Chapter 4: MANUFACTURING ENGINEERING'S ROLE IN IPPD

4.1 Introduction

In the collaborative design process, which characterizes Integrated Product, and Process Development (IPPD), the prime contractor, the major subcontractors/suppliers, and the government customer work together in an Integrated Product Team (or IPT) environment. The objective of the IPT is to help refine user requirements and transform them into a performance-based system or component specification, and then to provide a plan for effectively executing, validating and verifying a design that fulfills these performance requirements. An essential condition of the IPPD environment is that the contractor's manufacturing engineering function be directly involved early in the product definition process. Another essential condition is that the government Manufacturing Systems Engineer (MSE) actively participates in, and where appropriate leads the government's participation on IPTs throughout all phases of a program. This chapter describes the IPPD process and the roles of the contractor's manufacturing engineering (ME or CME) function as well as the government's MSE.

In the earliest phase of a new weapon system acquisition, the development of the user's requirements initiates an interactive process involving both the government customer and prospective contractors. These requirements are defined, evaluated, and prioritized with respect to budget and schedule constraints. Processes such as Quality Function Deployment (QFD) may be used in this environment to focus all parties on the most essential elements of these requirements and to define interdependencies.

Pre-proposal efforts and exchanges serve to inform the prime contractors of the customer needs. These include a continuing dialogue with industry, study contracts, advanced technology demonstrations, reviews of draft documents, and technology maturation contracts for risk mitigation. Contractor feedback to the government during this period assists in identifying the cost and risk drivers in the proposed acquisition.

The sequence just described is different in a number of respects from the more traditional approaches used in earlier acquisition programs. In the IPPD environment the participants interact freely throughout the design and development process. They exchange information and analyze cost, schedule, and performance trades, in accordance with an open communications philosophy. This interchange tends to eliminate the potentially adversarial relationship that has previously existed.

Joint contractor/government (supplier/customer) IPTs are encouraged. The sharing of each parties knowledge can lead to improved design, better understanding of parts capabilities, and most importantly can help create innovative solutions to problems when encountered. It is incumbent upon all parties in this cooperative arrangement to assure that sensitive and proprietary information is protected.

The IPT must assure their inputs into design trades balance the product design with the manufacturing processes. This requires accurate information about the capabilities, not limited to the factory floor, throughout the value chain, including all partners and suppliers. The MSE must identify and assure that all IPT members have access to the data and analytical tools used to define the process capabilities. As the design evolves, the fabrication and assembly options become constrained by the details of the

design, materials selection, imposed tolerances and by the other physical aspects of the proposed part. The MSE must be able to translate the consequences of the design decisions into producibility and affordability metrics. These values will help the IPT make informed and balanced trades among design options. The ME's role is to assure that producibility is optimized through the robustness of the product design as well as the processes. There will be occasions, due to design or other changes, that this or earlier phases will need to be re-examined due to changes or problems encountered in the production phase. A major modification or integration of additional capability into a production program may result in activities by government Systems Program Offices (SPOs) that are essentially new developments from the IPPD perspective. The roles of the MSE change from phase to phase. The earliest activities place emphasis on matching product requirements with the materials and process capabilities which impact performance, drive cost or introduce schedule risk. As the program transitions to EMD, the level of involvement increases as the details of the design evolve. Some of the changes between Pre-EMD and EMD by section are as follows:

- Design trade studies criteria must include producibility and affordability measures, whose impacts increase as the design matures.
- Cost models are updated at appropriate intervals.
- Materials selections lead to process requirements.
- Process requirements are matched with the process capabilities.
- Key characteristics are defined and identified on appropriate documents.
- Risk mitigation activities are launched for process capability improvements.
- Manufacturing simulations are used to verify product and tooling fit.

There will be two distinct types of MSE activities during the production phase. The first will focus on improving the efficiency of the existing or derivative manufacturing processes (variability reduction, VR). The second will be IPT participation in the integration of major systems improvements or engineering changes. Variability reduction will be addressed as a unique MSE activity in the rest of this section. Improvements and engineering changes should be treated by the MSE as if they were new starts, that is, by referring back to the appropriate place (Pre-EMD or EMD) in the MDG.

To ensure that affordability and manufacturing issues are fully addressed during the acquisition process, government personnel at the SPO may wish to use the Recommended RFP/Proposal Content sections of this chapter in generating RFPs and evaluating contractor responses. Contractors should be encouraged to review the contents of the MDG for guidance in preparing their proposals.

4.2 Rationale

The objective of the EMD phase is engineering *and* manufacturing development, not engineering *then* manufacturing development. The IPT must be as concerned with the ability to manufacture the proposed design as with its functionality. Just as component testing confirms the proposed parts

functionally, the MSE must have the same quality of data about the manufacturing process to fairly represent the *ability to manufacture* the parts. Process capabilities from the existing factory floor or data collected from benchmark industries can be used by the MSE to help establish the basis for affordability analysis. Unique materials or tolerances for which manufacturing data does not exist may require process testing, demonstration, or simulation by the MSE. These efforts would be functionally equivalent to the testing that is currently done by the design engineer to reduce risks on new component designs.

The transition to production at the end of EMD has traditionally brought with it many unpleasant surprises in the form of producibility changes needed to resolve low process yields, poor quality, or failures in assembly and final check out. Low Rate Initial Production (LRIP) was introduced as one mechanism to mitigate the transition to production risks. LRIP does not address the root cause of the transition to production problems, however. If LRIP is used effectively during the formal EMD phase it allows the problems that surface to be resolved without jeopardizing the production phase of the program. MSE activities must encourage an earlier focus by the IPT on the root causes of affordability, producibility and manufacturability problems. Focusing on these problems during development helps prevent transition to production problems. If problems do arise the emphasis must be on identifying and correcting the root cause of the deficiency.

Involving the manufacturing systems engineering function early in the product definition process, the IPPD team paves the way for prevention or early identification and mitigation of producibility, cost, and other risk areas in the transition-to-EMD or production. (In the previous acquisition environment these were classic contributors to cost and schedule overruns.) The contractor's formal IPPD procedures and processes should detail the roles, responsibilities, and authority of the MSE function in the IPT. They should ensure that all the resources, skills areas, data and tools needed for the IPPD are identified, available to the team, and effectively utilized. One of those roles that should be assigned to the team member(s) performing the manufacturing system engineering function is to lead producibility studies and analyses conducted by an IPT when product or process design might be influenced.

During CE and PDRR, the manufacturing engineering, production operations, quality, tooling design and fabrication, industrial engineering, and supplier members of the IPTs should focus on critical producibility, manufacturability, and affordability issues associated with the design. The selection of materials based on performance requirements, for instance, leads directly to the identification and evaluation of processes that may require further development. The EMD role becomes one of preparing the initial planning to support the build of the pre-LRIP test units and the LRIP planning to assure an optimal production design and associated processing definition. As materials are selected the appropriate manufacturing processes and equipment must be selected. To assure the proper matching with requirements, process capability data must be analyzed. Contractor’s and suppliers throughout the value stream should be encouraged to establish and populate a Manufacturing Capabilities database identifying present capability and areas where action is required to improve. Where a mismatch exists, capabilities must be improved or changes to the design or design requirements must occur to reduce cost and schedule risk. Variability reduction in the production phase requires the MSE to use selection and prioritization tools, such as the Pareto analysis and Quality Function Deployment (QFD), to find and focus on the processes most critical to the program success or to provide the best return on investment.

Other approaches to prioritizing improvements include simulation of the factory and cause and effect analysis of factory quality data. Regardless of how candidate processes are selected, the objective for the MSE is continuous improvement of the efficiency and effectiveness of factory operations.

Candidate processes should also include the support operations or "above the factory floor" activities. Analysis and use of data, management by fact, should be the basis of all decisions.

As the program moves into Production, the MSE become leaders in the continuous improvement of the product and processes. In this phase the IPT has two areas of focus. First, using the field and factory data, the manufacturing processes are examined to see if they can be made more robust (processes, like products, are susceptible to variation in inputs, environments, etc. - reducing this susceptibility improves process robustness) or their variation reduced. Second, if new performance requirements are identified, the design improvements are planned and introduced in a disciplined manner such as block changes. With the Statement of Objectives (or SOO) defining the expectations of the customer, the contractor's formal documentation of the IPPD process (and the roles and responsibilities of the participants) helps assure that no design decision takes place without the impact on manufacturing processes being defined.

Contractors who are experienced in the successful application of IPPD processes have developed "best practices". These practices are designed to clearly support quality and manufacturing policies. Many contractors now require careful examination and improvement of process flows. Beginning with the initial development of performance-based requirements by the customer, and by the IPT in the CE phase, QFD or similar methods are employed to focus on the best design responses to a set of requirements. The contractor typically hosts the QFD-type activities in the CE phase as a vehicle for further clarifying the design performance objectives. This has proven to be an excellent means of addressing any remaining cost and performance trades, and of increasing customer/user confidence in the team's approach.

4.3 Guidance

The contractor should demonstrate an understanding of and experience with IPPD deployment, including how the proposed program management structure utilizes IPPD concepts. IPT participants should be specially trained in the principles of IPPD as well as the design tools that will be utilized on the program. The contractor should document how IPPD processes will be employed on the program to assure that all participants understand their roles and responsibilities and perform accordingly. In particular, the contractor's procedures and policies should define the expected outputs from the team, with special emphasis on trades. Design trades should reflect the performance capabilities of the manufacturing processes available for the fabrication and assembly of the proposed design. The MSE focus is on the matching of process capabilities with product requirements, since this is a major source of cost and schedule risk in a program. The MSE and contractor with his supplier counterparts on the IPT, work in concert to assure that risks are identified, abated and managed throughout the program.

The contract should provide for a review of the performance requirements and the operating environment of the weapon system. The output of this review will be used to perform analysis of the requirements to identify the most crucial features, identify key characteristics and match processes with design features. Various methodologies to accomplish this may be used. Identification, validation and verification activities for all requirements will be supported by the MSE. With the emphasis on affordability, the cost-versus-performance trades made prior to the release of the System Requirements Document should be carefully reviewed with the contractor.

The contractor's Manufacturing Engineer and the MSE participate in the IPT to the extent required by program and tasks. For a large weapon system procurement the contractor may assign several MEs, including representation of several sub-disciplines such as Tooling, Test Equipment, Industrial Engineering, and Process Engineering, as well as product quality assurance. The government involvement may include full time assignments for an MSE and a Quality Engineer who participate in the IPT and provide government insight. However, with contractors who fully embrace MDG philosophies and openly communicate with their government counterparts, the necessity of full-time government participation should be reduced. The list that follows identifies the Pre-EMD tasks that should be performed by the contractor ME on the IPT. The MSE's responsibilities include insight to these tasks. See Chapter 7 for additional details related to these tasks.

- Participate in design trade studies
- Develop preliminary Production Cost Model (PCM)
- Initiate mapping of the Key Characteristics Process for requirements
- Establish data collection for process capability requirements
- Initiate process development as required (when data reveals process capability is less than desired to ensure a match between product requirements and process capability)
- Verify production flow through simulation
- Assure Key Supplier involvement
- Participate in Integrated Risk Assessments

In the EMD phase the activity levels of the ME and MSE increase with the detailing of the concept design. Key characteristics are identified and must be mapped to key process parameters, which are then evaluated against the contractor's manufacturing capabilities. Areas where the chosen materials or capabilities of the chosen processes do not support the design result in a design change, a process development, or other action to mitigate the risk. The initial manufacturing planning for LRIP occurs during EMD. Many contractors use assembly simulation tools to evaluate part-to-part and part-to-tool fit during this phase. The level of detail of the PCM is increased and actions are usually required to prevent cost growth during EMD.

MSE focus should be on aspects of the contractor program that increase risk to production. Key areas of interest include evaluating the robustness of the design and processes to meet the requirements; understanding the process capability issues and monitoring the required process improvements; evaluating the LRIP planning; and validating the PCM. EMD phase tasks for the ME and the MSE include the following (see Chapter 8 for additional details):

- Refine and monitor PCM
- Participate in design trade studies
- Implement single process initiative and commercial specifications where appropriate
- Map processes to key characteristics

- Implement manufacturing capability assessments
- Integrate key supplier activities into manufacturing activity
- Develop LRIP production plan
- Validate production plan through simulation
- Implement variability reduction
- Implement defect prevention activities
- Participate in System Security Engineering as part of design engineering
- Participate in Integrated Risk Assessments and implement appropriate risk mitigation initiatives

The ME will be the focal point for helping deploy the philosophy and the enabling technologies from the SPO and the contractor facilities to both the design center and the factory floor. At all times the ME is a participant, and occasionally is a teacher or mentor to promote VR. Continuous improvement of the factory processes requires a disciplined approach to the analysis of process control data and field data. Identifying the causes of variation and creating affordable improvements is critical to achieving production cost goals. Product changes based on new requirements or opportunities to make value-added improvements by changing design requirements and increasing robustness are common occurrences in the Production phase. They require the application of best practices used in Pre-EMD and EMD. The MSE should be a major participant from the SPO during this phase of a program, providing liaison on technical issues and reviewing contractor process and yield data for insight into process improvement efforts. Production phase tasks for the ME and the MSE include the following (see Chapter 9 for additional details):

- Monitor process variation and initiate improvements.
- Plan for cost-effective implementation of changes.
- Implement Lean initiatives for cost management.
- Maintain the PCM.
- Continue defect prevention program.

4.4 Lessons Learned

The use of IPTs working within the IPPD process has demonstrated clear benefits in reducing product design time and cost. With representatives of all stakeholder functions involved from the beginning, the team integrates the design, manufacturing, quality, and other key personnel into a focused, results-driven unit. The inclusion of customer and supplier personnel has further increased the effectiveness of IPTs in achieving high quality product definition. Most of the DoD's more recent product design efforts have

employed IPTs and reported both cost and schedule benefits. The number of engineering changes has been reduced, resulting in shorter design development times and reduced labor, since rework of the design is diminished. Reductions in tooling design and fabrication costs as well as rework in LRIP and in early production are additional benefits of the IPPD process.

Customer participation creates an atmosphere which supports cost-effective performance-based resolutions to design trades. Supplier participation provides a vehicle for a "best value" approach to the performance trades and cost objectives at the lower levels of the design effort. These benefits have made the disciplined IPPD approach the preferred approach for most defense contractors.

Factory cell teams or focus teams formed to address a production problem or station may replace design IPTs. Mastery of all the VR tools and techniques are not necessary, but the ME must have a good working knowledge of the full tool set of variability reduction techniques. Misuse of variability reduction tools can create misinformation and could adversely impact the processes. The maintenance of a Manufacturing Capability database derived from statistical process control and other factory data collection systems provides a source for continuous process improvement. The ME leads the problem solving process, addressing both the processes and the design to achieve a balanced and affordable product. Scrap/rework levels and cost have been significantly reduced, and schedule performance improved, by contractors applying these practices.

The ME's participation in planned product improvements provides the benefits described in Chapters 7 and 8 as parts of applicable contract phases are revisited. Additionally, product changes must be introduced into the existing factory in the least disruptive and most cost-effective manner. Changes to tooling and test equipment, processes, and the product flow require coordination and planning. Successful companies have used the ME to model before and after processes, employing simulation techniques to reduce errors which would impact cost and schedule.

4.5 Links to Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

See Pre-EMD SOO, EMD SOO, and Production SOO

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program)

Milestone II (Approval to Enter EMD)

Interim Event (corresponding to historical Preliminary Design Review):

Interim Event (corresponding to historical Critical Design Review):

Interim Event (corresponding to historical System Verification Review):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

Manufacturing Development Guide

Chapter 5: ENGINEERING FOR AFFORDABILITY & PRODUCIBILITY

5.1 Introduction

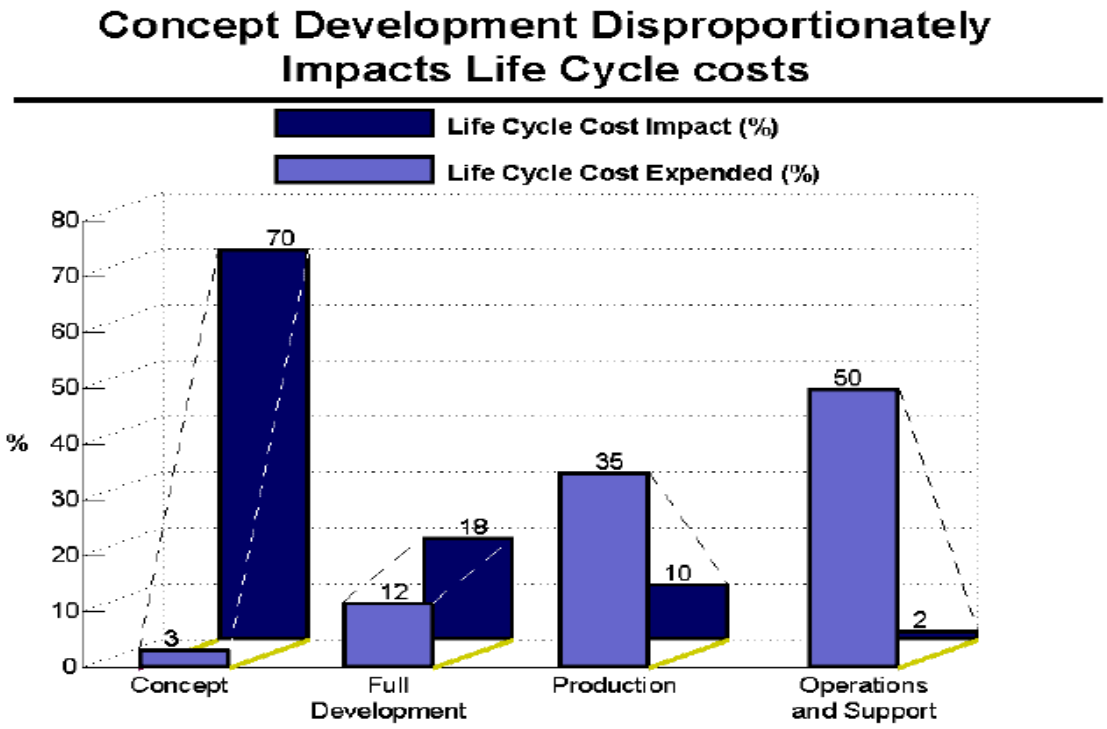
One of the primary purposes of the MDG is to improve product affordability. This chapter provides a general discussion of several approaches. Today's acquisition environment is highlighted by a competition among weapon systems for limited procurement dollars making affordability as critical as performance. Engineering for affordability must be performed during all phases of a program for both new developments and modifications.

In general, there are four approaches to engineering for affordability which can be combined as necessary to create the best tool for the circumstance: (1) affordability as a foundational responsibility for all engineers; (2) a dedicated producibility program; (3) a distinct affordability program; and (4) a value engineering program.

5.2 Rationale

Limited defense budgets mandate programs be significantly more affordable. This environment has led to major changes in the way development programs are managed and executed. Life Cycle Costs are now a crucial factor in determining weapon system feasibility. All new programs must emphasize cost as a primary contract requirement and must analyze the cost impact of all systems requirements.

Studies have repeatedly shown that the best opportunity for reducing system cost occurs during the early phases of program development (Figure 5-1). As the chart depicts, a small percentage of the life cycle cost is actually expended in the early phases but the decisions made in the concept development phase drive the majority of the life cycle costs. Therefore, it is critical that IPTs utilize affordability enhancing practices as soon as possible.



Source: **Producibility Measurements Guidelines**, NAVSO P-3679, Dept. of the Navy, August, 1993

Figure 5-1. Impact of Early Activities on Life Cycle Cost

Several factors have driven increased weapon system's cost, many of which are rooted in increasingly rapid technological advancements. Design complexities and integration difficulties often result in extended development times and increased costs. Long development cycles also increase the risk of diminishing manufacturing sources (also referred to as obsolete parts). This drives the costs for redesign, production, and maintenance and forces the AF to develop or pay a premium to maintain sources for old parts in a market where they have only a limited military application.

5.3 Guidance

Affordability as a Foundational Discipline: First, government and contractor senior leadership must explicitly direct that affordability is the responsibility of every member of the program, not an element applied solely by manufacturing engineers. This is analogous to the concept that quality ("Big Q") is everyone's responsibility, not just the Quality Assurance organization.

Second, management must continually place an emphasis on Life Cycle Costs. Design-To-Cost (DTC) and Reduction of Total Ownership Cost (RTOC) programs provide a management framework to help assure affordability requirements are met. DTC and RTOC programs both allocate (or partition) the overall cost requirement down to lower level IPTs where each is given its own cost targets, goals, or requirements. The overall program cost requirements may be defined in different ways (as shown in Figure 5-2), depending upon how much of the cost is to be included. Traditionally, DTC goals usually focus only on flyaway costs and RTOC initiatives focus on total Life Cycle Costs (LCC).

A common approach for characterizing the overall program cost requirement is to use the Average Unit Production Price (AUPP). AUPP may be defined as the flyaway cost divided by the production quantity. In some cases, the cost of support equipment is added to the flyaway cost.

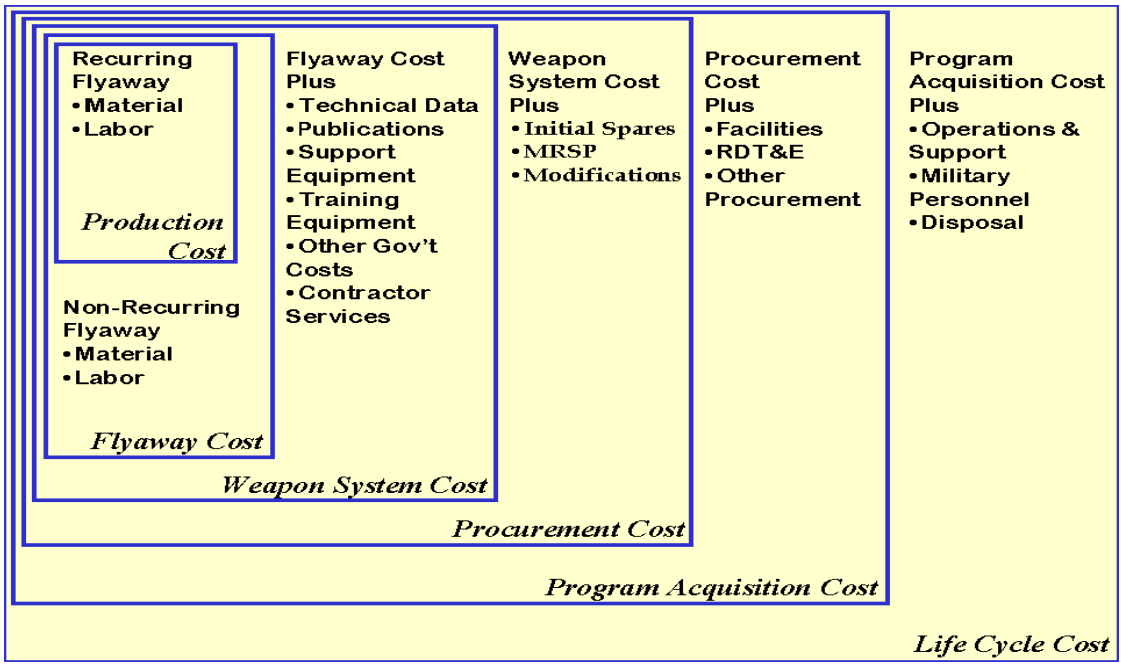


Figure 5-2. Life Cycle Costs - Total Ownership Costs

Third, management must also provide tools to all engineering disciplines to analyze and optimize cost in their areas. The tools must have the flexibility to trade product performance against projected production costs. Production Cost Models (discussed elsewhere in this guide) should be used to estimate the impacts of design decisions on manufacturing costs and evaluate design alternatives within the context of affordability. IPTs should also develop and maintain affordability metrics and analyze them as part of their continuous improvement activities. Historically, this has been done under a Design-to-Cost program, where each IPT monitors their progress towards meeting an allocated cost goal.

A Dedicated Producibility Effort: Three tools/practices contribute significantly to improving producibility when integrated into the Systems Engineering process: Design for Manufacturing & Assembly, Manufacturing Capability Assessments, and Determinant Assembly.

Design for Manufacturing & Assembly (DFMA) is an affordability tool widely accepted for facilitating cost reduction activities. It includes design guidelines for improving the ease of assembly, such as reduced parts count, minimizing types of fasteners, and multi-use parts. Monolithic parts (larger parts which contain smaller parts such as brackets and stiffeners that are forged, cast, or machined integrally into the basic part) can also reduce assembly time. DFMA also includes a methodology to evaluate proposed designs to determine how well they incorporate the DFMA principles and to provide a measurable assessment of the design's producibility.

Manufacturing Capability Assessments (which are described in other sections of this guide) relate to

engineering for affordability by providing the design engineers an understanding of manufacturing capabilities. These capabilities should be fed back into the design to result in a more producible product, consistent with the inherent capabilities of the existing processes.

Determinant Assembly is an approach used to significantly reduce tooling costs. It relies on self-locating parts that have locating features directly on each mating part, as opposed to relying on expensive tools and fixtures for part placement.

A Distinct Affordability Program: To increase the focus on affordability, some programs have implemented a separate affordability program. An Affordability Program Plan should be developed to describe the program, processes, and roles and responsibilities of the contractor and government. The primary processes within an affordability program include: identifying cost drivers; developing potential initiatives (or projects) for reducing these costs; evaluating the cost/benefits of each potential initiative; reviewing, ranking (prioritizing), and approving each initiative for implementation; and monitoring their implementation. To fund these projects, the government must have a separate pot of money for the investments or the program team must develop a unique contractual arrangement to incentivize the contractor to invest their money.

A Value Engineering Program: Value Engineering (VE) is an organized effort to analyze the functions of a system for the purpose of achieving the essential functions at the lowest life cycle cost, while still meeting all performance requirements. VE programs can either be ongoing, level of effort tasks to continually look for design improvements, or case-by-case submissions of ideas. Under either approach, the contractor will submit Value Engineering Change Proposals to the government and may share in the projected savings if they are approved. The Federal Acquisition Regulations (Part 48) provide more detailed guidance on cost and savings sharing arrangements and contractual requirements.

5.4 Lessons Learned

DFMA has been very successful where it has been implemented. Figure 5-3 presents a summary of the benefits obtained from the application of Design for Manufacturing and Design for Assembly processes in 66 published case studies. (Source: "A Decade of DFMA Research," G. Boothroyd, Proceedings of the 1994 International Forum of Design for Manufacture and Assembly, from the June 13-14, 1994 edition.)

Category	Number of Studies	Average Reduction (%)
Part Count	55	57
Separate Fasteners	12	72
Assembly Time	37	63
Assembly Cost	16	45
Product Cost	15	51
Product Development / Time to Market	4	50
Manufacturing Cycle Time	6	58

Figure 5-3. Design for Manufacturing and Assembly Results.

Conversely, previous experience with DTC has been disappointing. It can be erroneously applied as an "accounting afterthought" by merely booking changes to the cost estimate as opposed to providing direction on where to focus cost reduction activities. DTC programs must also rely on a current Production Cost Model which is continually updated to reflect programmatic changes.

Finally, experience shows the use of affordability engineering practices is most effective when they are flowed down to major/critical suppliers. Under acquisition reform, as the government begins to relinquish control of the detailed design back to the prime contractor and suppliers, those suppliers with design authority must also employ affordability tools and techniques.

5.5 Recommended RFP/Proposal Content

System Specification Requirement

Government Statement of Objectives (SOO)

See Pre-EMD SOO, EMD SOO, and Production SOO

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program):

Milestone II (Approval to Enter EMD):

Interim Milestone (Corresponding to Critical Design Review):

Milestone III (Approval to Enter Production):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

Manufacturing Development Guide

Chapter 6: QUALITY SYSTEMS

6.1 Introduction

Within the context of a foundational quality management system such as ANSI/ASQC Q9001 (ISO 9001:2000), it is often beneficial to implement tools and techniques which go beyond traditional quality management to ensure the final product meets user needs. Such tools and techniques focus on the development of producible, maintainable products and on stable and capable manufacturing processes. They are especially useful for assuring the quality of highly technical, state-of-the-art products and processes. Integrating the use of these state-of-the-art tools and techniques with their foundational quality systems, some companies refer to their quality systems as advanced quality systems. They may also refer to Advanced Quality Techniques or use similar terms. Elsewhere, in order to emphasize that accountability for the quality of work should be placed on those performing the work, these tools and techniques are considered part of a Systems Engineering process or Integrated Product and Process Development (IPPD) system. Regardless of the terms used, it is engineering and manufacturing personnel who should be implementing tools and techniques whose primary purpose is to prevent the generation of defects in the products being produced. It should be kept firmly in mind though that all personnel throughout all aspects of the business are responsible for assurance of quality in all activities.

This chapter discusses quality systems and their evolution in order to bridge the gap between traditional defect detection quality control methodologies and current state-of-the-art methods used to assure quality. Many of the specific practices addressed elsewhere in this guide are grounded in modern quality system tools and concepts, including key characteristics, variability reduction, supplier management, virtual manufacturing, and product and process validation. This chapter doesn't repeat what is found elsewhere, but addresses an overall systems approach for assuring quality. Elsewhere in this guide, the tools and techniques that make up state-of-the-art quality systems are referred to as *defect prevention techniques*. This is consistent with similar guidance documents that have been developed through other acquisition reform efforts, such as the Joint Aeronautical Commanders Group (JACG) document titled *Engineering and Manufacturing Practices for Defect Prevention: A Guide for Aerospace Acquisition Management Teams*. This is the prime source for state-of-the-art quality system requirements. Section 4 of the JACG policy guidelines discusses attributes, tools, and business practices associated with successful modern Quality Management Systems. Further information on defect prevention tools and processes not discussed in the MDG itself can be found there. These principles are applicable to all phases of an acquisition program.

To ensure that issues related to quality systems are fully addressed during the acquisition process, government personnel at the System Program Office may wish to use the Recommended RFP/Proposal Content sections of this chapter in generating RFPs and evaluating contractor responses. Contractors, in turn, should be encouraged to review the contents of the MDG for guidance in preparing their proposals.

6.2 Rationale

Where conventional quality systems have emphasized the detection of defects after the product has been produced, state-of-the-art quality systems are designed to prevent the production of defective products. Quality systems concepts and practices as defined will reduce manufacturing risk and assist in risk management as stated in Chapter 7, section 3. Advanced quality concepts and practices implemented early in systems design and development will not only minimize program risk but also reduce the amount of manufacturing process controls required, along with subsequent process oversight. Quality systems concepts and practices will also affect technical data development, particularly the product design and definition of technical baselines (see Chapter 3, section 2.5)

As deployed by world-class companies around the globe, modern state-of-the-art Quality Systems are implemented outside the traditional quality assurance organizational structure. With the widespread acceptance of TQM philosophies, personnel in value-added function areas (rather than dedicated quality personnel) are tasked with responsibility for the quality of their own work and empowered to make key decisions affecting that work. (*Value-added,* as used here, refers to work performed by direct labor functions which adds tangible value directly to the product being produced.) . In response to these developments, some companies have begun questioning whether there is still a need for an independent, dedicated quality functional organization.

However, far from eliminating the need for quality professionals, the acceptance of responsibility for their own work by other members of an organization frees up the modern quality organization to perform work consistent with the long-term focus of state-of-the-art quality systems.

6.3 Guidance

In the IPPD acquisition environment, Quality Engineers, like manufacturing engineers, are key members of the program IPT. They participate directly in every part of the program, from the CE and PDRR phases of the design process all the way through to production and support. Their role is to ensure an integrated, multi-functional approach to quality throughout the product life cycle.

A good quality system should satisfy three top-level objectives: (1) It should achieve and sustain the quality of the product and continually meet the customer's needs; (2) It should provide confidence to management that the appropriate level of quality is being achieved and sustained; (3) It should provide confidence to the customer that the appropriate level of quality is or will be achieved in the product provided. No one prescribed system is preferable to all others in meeting these objectives. Systems vary from company to company, and the application of a system may also vary from acquisition to acquisition depending on the complexity of items and the requirements levied.

Despite the differences in details of various companies' quality systems, certain features will be included in all state-of-the-art quality systems:

- A formal quality management structure, quality policy formation and deployment information, and the traditional quality control and assurance functions (inspections, tests, etc.), as needed, will be part of the quality system.

- The system will extend to all facets of a company's technical, support, and management processes and all business processes and products of the organization.
- The system should be cost effective and should accommodate the present contract and circumstances.
- Methods for root cause identification of defects and elimination of those causes, and continuous improvement techniques, should be integral to all quality systems.
- Internal management audits should be performed by quality auditors having independence from the organizations they audit and the audit results should be used to help management understand how well processes are performing throughout the organization.

The quality professionals who work in the modern quality assurance organization should be more than a police function. They should help solve problems that are identified and effect needed improvements. Quality assurance organizations should exist to further the goals of the organization.

In accordance with DOD 5000-2.R, paragraph 4.3.2, "the quality management process shall include the following key quality activities:

1. Establishment of capable processes,
2. Monitoring and control of critical processes and product variation,
3. Establishment of mechanisms for feedback of field product performance,
4. Implementation of an effective root cause analysis and corrective action system, and
5. Continuous process improvement.

Other quality related responsibilities might include:

- Determining how well systems are working and ensuring that functions and product/process teams are effectively integrated.
- Training of personnel in the use of state-of-the-art quality tools and techniques.
- Helping to deploy these tools and techniques.
- Identifying improvement opportunities in all company processes, including management, engineering, manufacturing and support processes, helping to develop feasible improvements (rather than just telling others that they need to improve), and helping to implement the improvements.

The personnel in modern quality assurance organizations should be experts in state-of-the-art quality systems, management processes, and defect prevention tools and techniques. They should be involved with IPPD teams in the earliest phases of the development process and throughout the product life cycle. They should always be available to the IPTs for consultation. Depending on the circumstances, the traditional role of independent inspector/tester quality personnel may still be necessary, (flight safety or

other mandated inspections i.e.) but the main focus should be proactive support rather than reactive policing. Quality personnel should provide the quality tools and quality perspectives needed to support the personnel who are directly adding value to the product, rather than distributing notifications when they discover non-conformances. Recommended work statement content for an over-arching state-of-the-art quality system is provided in subsequent subsections and is in accordance with JACG guidance. It is recommended that a discussion of the overarching quality system requirements be included in the RFP technical section under the evaluation factors for award if quality is a significant risk.

6.4 Lessons Learned

Traditional quality systems have often been proven to be ineffective in assuring the quality of the final product - i.e., in assuring external customer requirements are met by preventing the generation of defective product. In fact, the best that traditional, inspection based, quality systems could hope to do was to identify all defective product that was produced and prevent its delivery to the customer. Even 100% inspection, however, has been shown to be less than 100% effective in identifying all defects. In addition, the role of the quality professional as policeman, looking for infractions, writing citations when they find one, and walking away to let the violator deal with their problem, has led to mistrust, lack of team synergy, and adversarial relationships. The prevalent culture also led many to believe it was the inspectors, not the people producing the product, who were responsible for quality of the product

To deal with this negative environment, some companies, in the name of TQM, eliminated inspectors and told manufacturing personnel they were now responsible for their own work. What they often found, however, is that as long as independent inspectors are finding defects they still have an important role to fill. It is only after they stop finding defects, assuming defects are no longer being produced, that inspectors are no longer needed (even then, it is often wise to continue some level of objective, statistical-based inspections as a verification of the continued stability and capability of the manufacturing processes.) Inspection, however, should not be the primary role of quality organizations. Much more is to be gained from the work of quality professionals by having them work with processes, personnel, and other resources to create and sustain a culture of continuous improvement.

Another lesson that many world-class companies have learned is that quality professionals need authority to go with their responsibilities. As is readily evident with even a cursory review of applicable literature, the most important principle related to successful implementation of quality assurance systems is top management commitment. Numerous companies have discovered that permitting short-term gains and immediate schedule concerns to unduly influence decisions often keeps them from realizing promised benefits of comprehensive quality systems. Many companies that have taken a good hard look at themselves (usually only after reaching the brink of disaster), have often discovered that over the objections of quality assurance personnel, process workarounds had become the norm, rather than following disciplined quality processes. In response, many of these companies have elevated their top quality assurance executive. Directors and Vice Presidents in Charge of Quality, reporting to division, company, or corporate presidents, have become commonplace. Some companies have created Chief Quality Officer positions on the level of Chief Operating and Chief Financial Officers. Such companies have often found themselves vying for world-class status.

6.5 Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Exit criteria will be addressed as part of the specific practices sections in subsequent chapters.

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

Manufacturing Development Guide

Chapter 7: PRE-EMD PHASE GUIDELINES

7.1 Introduction

To fully realize the long-term benefits available through the use of the MDG practices, the SPO and contractor must implement them as early in the program life cycle as possible. A pre-requisite for effective implementation of the MDG practices is the participation of the manufacturing engineering (ME) function in the early development of the IPPD process. The large number of MDG practices that fall under the manufacturing umbrella functionally should emphasize the necessity of manufacturing engineering participation.

During the Pre-Engineering and Manufacturing Development (Pre-EMD) program phases, the MDG objectives are met by involvement of the manufacturing engineer and by stressing the importance of production cost as a high priority product design requirement. The focus of this chapter is the early product development process. Emphasis is placed on evaluating the producibility of design options so that production risk and cost can be appropriately traded off with system performance. In addition, the foundation of defect prevention techniques is laid in preparation for further implementation in the EMD and Production phases.

7.1.1 Suggested Pre-EMD Statement of Objectives (SOO) Content

7.2 Production Cost Modeling

7.2.1 Introduction

In an Engineering for Affordability environment, earlier and increasingly accurate Production Cost Modeling becomes extremely important. The Production Cost Model (PCM) should be developed and used in conjunction with system performance and effectiveness simulations so that the cost impacts of design alternatives can be quickly evaluated. The PCM should be continuously refined as the design definition improves, and should provide the basis for the production cost requirement that will be established for Engineering and Manufacturing Development (EMD). This cost requirement is often an Average Unit Production Price (AUPP).

7.2.2 Production Cost Modeling Rationale

The need for significantly more affordable Department of Defense (DoD) programs in a limited budget environment has created a need to better understand the cost impacts of design decisions during initial system development. Cost modeling tools are essential for conducting the cost and performance trade studies that are needed to make informed design decisions.

The PCM will also play a key role in assessing the overall progress of the development program. Current cost estimates and trends at Integrated Master Plan (IMP) milestones, plus the status of current and planned cost risk abatement efforts, will become a part of the determination of whether to proceed to the next phase.

7.2.3 Production Cost Modeling Guidance

Accurately modeling production costs with high fidelity during the pre-EMD development activities is extremely difficult. This is because inputs to the PCM and production cost estimates, initially calculated as rough order of magnitude (ROM) estimates, will evolve throughout the Pre-EMD phase activities. At all times, however, they should reflect the best possible estimates based on current development status, and should serve to identify those cost issues that need to be addressed by formal mitigation activities. To the maximum extent possible, the PCM should be a joint effort between the contractor and the government. Each group should work together in an IPT environment to define the overall architecture, input requirements, groundrules & assumptions, levels of detail to be included, and output formats.

Many commercial cost models are available for use and/or adaptation to fit company-unique accounting systems. The level of detail and the complexity of the cost models appropriate for a product will vary depending on the product's complexity, the program size, and related factors. In order to perform real-time cost and performance trades efficiently, cost models should be linked to the performance simulations used for evaluating the technical merit of potential designs. The PCM established for the baseline system concept should be refined as the concept develops. The objective is to predict the program cost impact of production rate and delivery schedule variations, and to provide a projected production cost for evaluation against the production cost requirement upon entering EMD. On some programs, a Life Cycle Cost Model may be required for projecting support, maintenance, spares inventory, storage, and disposal costs.

7.2.4 Production Cost Modeling Lessons Learned

Studies have repeatedly shown that the best opportunities for system cost reduction occur during early program development phases. The early initiation of production cost modeling supports cost reduction activities by helping to identify the areas with the greatest potential for payback.

Previous experience with Design to Cost (DTC) approaches has been disappointing. In many cases, the ground rules and assumptions that fed production cost models (rate, volume, schedule) were not updated to reflect program changes and so the production cost estimates produced by the DTC activities had no validity. To be effective and credible, the Production Cost Model must be maintained, and kept current with all program ground rules and assumptions.

7.2.5 Production Cost Modeling Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program):

Milestone II (Approval to Enter EMD):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

7.3 Manufacturing Capability Assessment and Risk Management

7.3.1 Introduction

The manufacturing capability assessment and risk management effort is a structured, disciplined approach to evaluating available and forthcoming manufacturing capabilities in order to identify and assess risk early in the design process. Risk is defined as any factor which could cause a program to miss a goal, objective, or performance requirement, or to exceed cost or schedule constraints. Once risks are identified, the IPT can develop and execute risk mitigation plans in order to maintain an acceptable level of risk throughout the acquisition program and the product life cycle. In the past, designers often did not consider technology maturation issues and the associated risks until the demonstration and validation effort, or even later.

One source of risk, for instance, is the selection of materials that could drive the use of new processes, immature processes, or low-yield processes. The active participation of manufacturing engineering early in the IPPD process is intended to reduce the risk of transition to production and to reduce total program cost through the avoidance of engineering changes and rework later in the program. A prerequisite is a clear understanding of the relationship between manufacturing capabilities and the associated costs of achieving a producible and affordable design.

Because weapon system acquisitions often include multi-company teams and multiple subcontractors, the capabilities of teammates and preferred suppliers -- and the integration of GFP contractors -- must be considered in the risk management effort.

While risk is called out separately here in order to emphasize specific concerns related to manufacturing, manufacturing risk should always be fully integrated into the program-wide risk management effort. (This in fact is one of the key responsibilities of the manufacturing engineering representative on the IPT in the pre-EMD phases.) The principles set forth in this section should therefore be considered as continuous with the program management risk sections in the RFP, as well as with Systems Engineering and other relevant sections of the RFP. Design trade studies and requirements verification efforts will be the source of much of the risk identification and assessment.

7.3.2 Manufacturing Capability Assessment and Risk Management Rationale

The reduction of risk associated with manufacturing, transition to production, and final product cost must start with active manufacturing engineering participation on the integrated product team. Recognizing a high percentage of program cost is "locked in" by decisions made during the earliest phases of an acquisition program leads to a real appreciation of the importance of a balanced, integrated product team and preferred suppliers in the CE and PDRR phases.

From an affordability perspective it is generally accepted that the design features should reflect current rather than future process capabilities. The advantages of new materials and processes that offer weight, performance and cost benefits must certainly be considered, but the management of the cost, schedule

and quality risks associated with new materials and processes must be included in the consideration. These elements must also be balanced with the issues of sustaining industrial base readiness and key capabilities within an austere acquisition environment.

7.3.3 Manufacturing Capability Assessment and Risk Management Guidance

The contractor should demonstrate a formal process for identifying and managing risks associated with the manufacturing capabilities of the team and the preferred suppliers who will participate in the program. In the CE and PDRR phase the risk management effort should identify new materials and processes required *throughout* the supply chain. The risk management process should also provide performance metrics on known design features and processes, and on the relative capabilities of the team and its preferred suppliers to assure work is performed by the best qualified.

In particular, manufacturing risk management in the CE and PDRR phases focuses on using the IPPD process to anticipate areas of cost and schedule risk, and establish appropriate risk reduction efforts. The Program Office should tailor the RFP to address the industrial base sustainment issues that are to be included in contractor proposals. However, the fundamental responsibility for recognizing key component capacity constraints and providing adequate risk mitigation rests with the contractor. Contractors should be encouraged to identify the Internal Research and Development (IRAD) efforts and internal investments in materials and processes that are part of the risk mitigation effort for new acquisition programs.

Both government and commercial interests have developed several risk management tools and concepts. These include Manufacturing Capability Assessments (MCA), an Integrated Risk Management (IRM) process developed by the Air Force Aeronautical Systems Center (ASC); and pre-control concepts for risk management at the individual process level. For basic information and bibliographical information about the latter, see *Juran's Quality Control Handbook*, Fourth Edition, Section 24.

7.3.4 Manufacturing Capability Assessment and Risk Management: Lessons Learned

In the defense acquisition environment, risk has often become an issue when the contractor/government acquisition team overestimates technology readiness, downplays potential transition to production problems, or fails to plan and perform effective risk management. The results frequently have included cost overruns, schedule delays, and technical compromises. Initial impacts surface as early as PDRR and continue through succeeding program phases.

The importance of starting as early as possible prior to EMD in identifying potential manufacturing risks has been proven. It is important to identify parts with high manufacturing risk in Pre-EMD and to develop a process development/validation program for full-scale parts in EMD prior to creating a Build-to Package.

A close air support aircraft program from the mid-1970s in which the adverse consequences of not identifying and managing manufacturing capability risk had serious consequences provides a classic lesson learned example. It was discovered subsequent to source selection that the prime contractor was lacking both manufacturing capability and the capacity required to satisfy production aircraft delivery schedules. The Air Force ultimately had to furnish a significant quantity of machine tools and related production equipment to help resolve the shortfall.

This experience led to the establishment and institutionalization of Manufacturing

Management/Production Capability Reviews (MM/PCRs), conducted as an integral part of the source selection process. The first major MM/PCR was performed in concert with the Air Combat Fighter (later designated F-16) source selection in 1976. Positive MM/PCR results included not only the generation of critically needed inputs to Source Selection Evaluation Boards (SSEBs) and Advisory Councils (SSACs), but also led to greatly increased defense industry attention to production planning.

Early consideration of production issues in the Concept Exploration and PDRR activity phases is a key contributor to the lowering of risk for transition to production. A formal, disciplined risk management effort that is integrated into the overall program risk management plan (along with the early recognition of constraints associated with limited capacity, industrial base sustainment issues, and manufacturing capability issues) is essential to cost, schedule, and quality performance. Active participation of manufacturing engineering in the earliest IPT activities assures that all these constraints are addressed, and formally documented as part of the IPPD procedures.

7.3.5 Manufacturing Capability Assessment and Risk Management: Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program)

Milestone II (Approval to Enter EMD)

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

7.4 Key Suppliers

7.4.1 Introduction

Key supplier partnerships and strategic business alliances have become critical factors in today's defense system acquisitions. Partnerships foster joint commitments between companies and promote shared investments in product design and development. Resource sharing and mutually focused internal research and development activities result in aggressive, efficient problem solving and product development. It is not the intent of these guidelines to promote a business strategy of either exclusive partnerships or sustained competition. Rather it is to promote supplier participation in the program teaming structure and in proposal, development, and design activities as soon as the business strategy decision is made. This early supplier participation will allow the team to exploit complementary strengths, address weaknesses, and take mutual ownership of problems and solutions.

A key supplier (including suppliers of Government Furnished Property GFP) is a supplier at any level whose cost, schedule, or technical performance is essential to the development and production of an effective, affordable system. There are several criteria that can result in a supplier being deemed key:

- The requirements flowdown process, as shown in Figure 7-1, results in a supplier's "product characteristic" being essential to attaining the "system attribute requirement".
- A supplier is identified as "sole source" because of unique technologies or unique manufacturing capabilities.
- Excessive risk, in cost or technical performance, with no low-risk alternative available.

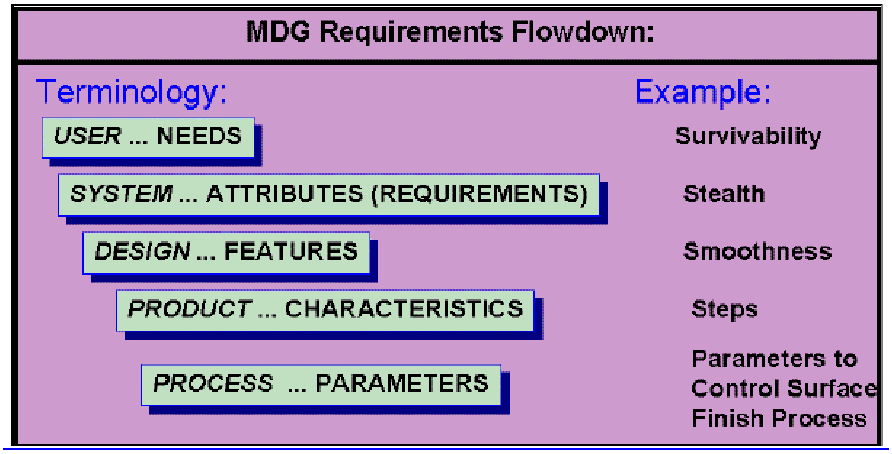


Figure 7-1. Requirements Flow-down Terminology

7.4.2 Key Suppliers Rationale

Supplier performance becomes increasingly important as the percentage of weapon systems work performed at the supplier level continues to grow. Various studies have shown that, once a program reaches production, supplier activities typically account for more than 60% of the total production cost. Key suppliers are responsible for the full gamut of program activities involved in system acquisition. They perform design tasks, trade studies, risk management, key product and process identification, and they further flow down authority to assure that their performance allocations are met. For these reasons it is essential to integrate key suppliers into program planning and development as early as possible so they can participate in the allocation of requirements and design trades as well as resource sharing during the development and detailed design activities.

7.4.3 Key Suppliers Guidance

Key suppliers should be integrated into proposal preparation activities and should contribute to Integrated Product and Process Development (IPPD) early to enable the program to take full advantage of their product, system, and process knowledge. Supplier tasks must be fully integrated into the overall program plans and schedules and a plan should be developed which fully describes the supplier management effort. Successful supplier participation in the IPPD process requires effective communication of the requirements and goals by the prime contractor. It is intended that requirement

flowdown be based on a cooperative agreement. The prime should have an established system for key supplier selection that includes criteria for past performance, proven abilities demonstrated on similar programs, and assessment of supplier capabilities for the technology in question. The system also should address supplier implementation of the practices described in this guide.

The use of Government Furnished Property, Equipment, Services, and Facilities (GFP) represents a special area of focus in the treatment of key suppliers. Communication and teamwork between the prime contractor and key GFP suppliers must be effective and continuous. This will require the Government to assure that its contracts with key GFP suppliers and the prime allow Associate Contractor Agreements (ACAs) which expedite communications in areas such as interface requirements, changes in design, risks, and schedules. Past programs have often been hampered by slips in delivery and integration problems when requirements and interfaces have not been effectively communicated to the key GFP supplier. The supplier management plan prepared by the prime contractor should address incorporation of key GFP supplier activities and schedules into the overall program plan. If an Associate Contractor Agreement is implemented on a program, the agreement must provide for the participation of key GFP contractors in IPPD arrangements and must allow adequate insight into key GFP contractor activities so they can be fully integrated into the Integrated Master Plan (IMP). If the contractor identifies a supplier of GFP as key and that supplier's contract with the government does not have adequate ACA requirements, the contractor needs to bring this to the attention of the government program office, who should effect the needed changes to the supplier's contract.

7.4.4 Key Suppliers Lessons Learned

Programs that have not successfully integrated their key suppliers into the overall schedules and plans have commonly had difficulties in meeting their requirements and goals. The supplier base was often neglected until after concepts had been developed and designs begun resulting in supplier product and process capabilities insufficient to meet program needs. System integration has often been hampered by interface difficulties, and the prime contractor has often had little insight into supplier slippage and risk areas. Past performance data on supplier capabilities was often lacking or given less weight than cost in selection activities. Supplier performance lead times were often optimistically factored into overall program schedules without margin for delays. Often, GFP Contractor requirements were not kept current with the Prime contractor's system design. Inadequate supplier risk assessment tools hindered risk identification and subsequent mitigation planning.

7.4.5 Key Suppliers Recommended RFP / Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval to Begin Program):

Milestone II (Approval to Enter EMD):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

7.5 Key Characteristics and Processes

7.5.1 Introduction

The identification of key product characteristics and key production process capabilities is a basic engineering task essential to successful manufacturing development. The objectives of this practice are: (1) identify product characteristics of the design which most influence fit, performance or reliability; (2) support the mapping of product characteristics to production processes; (3) enable the balancing of product design requirements with manufacturing process capabilities; and (4) enable the development of the required process controls for production.

Key Characteristic (KC) definition:

A feature of a material, part, assembly, or system in which variation from nominal has the most adverse impact on fit, performance, reliability, or cost of the part.

Identification of KCs should ideally begin in the phases prior to EMD, with the list of KCs continuing to be refined during EMD.

The concept of identifying key characteristics is linked to the Pareto principle, which asserts that a relatively small number of features will have the most significant impact on performance. This principle enables us to focus scarce resources on the most critical features and processes.

7.5.2 Key Characteristics and Processes Rationale

The practice of identifying KCs serves many purposes. Among them:

- Facilitating communication among design and manufacturing engineers by linking the competing objectives of performance and producibility together in a common point of reference on the part or system. Many KCs are interface characteristics, so their identification requires enhanced communication between IPTs as well as among contractors and suppliers.
- Identifying characteristics to be redesigned or eliminated in order to achieve a more robust product design.
- Identifying characteristics for which manufacturing process capabilities must be assessed (see Chapter 7, Section 7.3 "Manufacturing Capability Assessment and Risk Management").

- Identifying candidate key characteristics for future variability reduction activities (see Chapter 7, Section 7.6 "Variability Reduction").
- Identifying product characteristics that are most important and may require extra attention in the manufacturing process, such as the use of statistical process control techniques.

7.5.3 Key Characteristics and Processes Guidance

Identification of KCs: Contractors have used a wide spectrum of approaches for identifying KCs. Subjective approaches, such as general discussions and consensus among design and manufacturing experts may be used. More objective and rigorous tools are recommended, including Quality Function Deployment, detailed risk identification methods, or statistical analysis of yield and reliability data from similar products.

By definition, there should be relatively few KCs. Although there is no magic number that is universally applicable, each part may have 1-3 KCs, and most simple parts (such as clips and brackets) should have none. Once identified, KC status is not etched in stone. They are changeable over time and may be deleted as the design is changed. New KCs may also be added as the design is iteratively refined. If KCs are identified for assembly characteristics (such as fit, gaps, etc.), then the design for piece parts composing the assembly must be assessed to determine if KCs exist at the lower part/assembly level. Through this approach, higher level KCs may be flowed down to the lowest possible level to assure controls in fabrication.

A common question that arises is, “Should KCs be deleted when the manufacturing process is highly capable?” By definition, the status, capability, or maturity of a process is not a factor in the designation of a feature as a KC. KCs can serve as an important communication tool to other producers of key features. For instance, a part may be re-competed and made by a new supplier or turned over to a depot for sustainment support. In these examples, the continued designation as a KC communicates the criticality of the feature to the new supplier. If current processes are highly capable, the process control plan should be adjusted to reduce inspections. In addition, use of highly capable processes may reduce the amount of attention and documentation required.

KCs should be identified on drawings or in specifications. One method is to use a flag, as shown in Figure 7.2, which depicts KCs relating to low observability properties. A unique identifying number or label should be assigned to each KC so that related data can be tracked and mapped to the production processes that create the KCs.

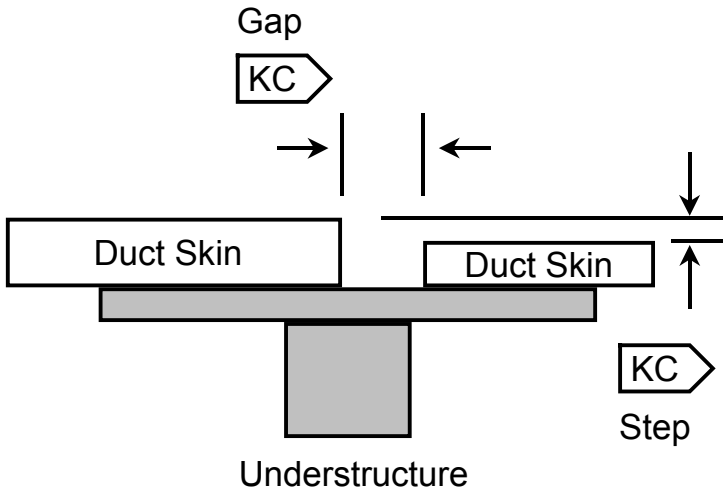


Figure 7-2. KC Flags on Drawings

Figure 7-3 shows a standard nomenclature that may be used when discussing key characteristics. It also demonstrates how identification of key characteristics can begin at the highest level of user needs and then flow down to the lowest possible level of process control.

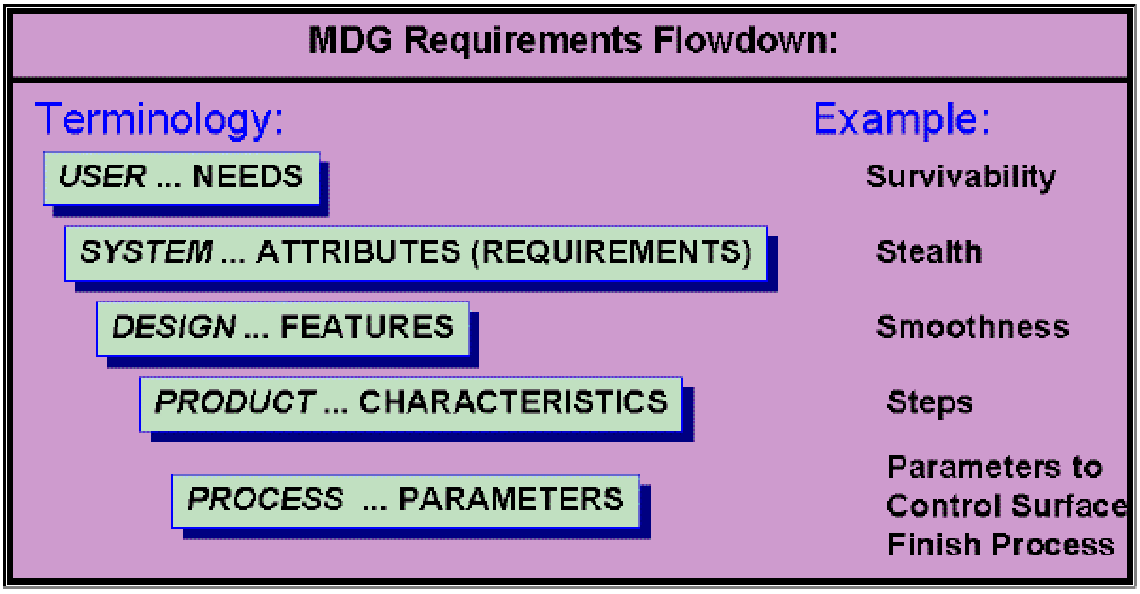


Figure 7-3. Key Characteristics Terminology

Mapping of Processes to KCs: Once identified, the team must determine which manufacturing processes create or significantly contribute to each KC. These processes are then termed critical processes. The contractor should maintain documentation depicting this relationship between each KC and their associated critical processes.

Suppliers: In some cases, the prime contractor may flow down specific key characteristics to a supplier, especially if the supplier is producing to a design provided by the prime. Suppliers who have design authority, however, should have responsibility to identify their KCs and critical processes. In

either case, the prime should have a systematic plan for managing their suppliers' production of designs and products with key characteristics.

7.5.4 Key Characteristics and Processes Lessons Learned

The benefits gained from improved communication and coordination among disparate organizations as a result of identifying KCs cannot be overstated. The process of having cross-functional (and often cross-company) representatives at the same table to determine critical interfaces, features, etc. can pay huge dividends. In a major airframe program, this coordination resulted in major structural sections fitting "like a glove," despite being designed and built by different companies, geographically separated, utilizing different materials and processes.

The identification of too many KCs can be a potential pitfall. Each KC costs the manufacturing organization money. They must develop control plans and collect, analyze, and act upon data. Too many KCs can be caused by: (1) misunderstanding of the definition of KCs; (2) overly cautious product design engineers who see KCs as an opportunity to tighten the reins on manufacturing; and (3) the desire for manufacturing data. In one large aircraft program, engineers chose weight as a KC, not because it met the definition of a KC, but because they wanted a great deal of weight-related manufacturing data (which they should have gotten through other means). Training of all IPT members is the key for preventing too many KCs from being chosen.

Metrics can be an area of conflict when it comes to measuring progress in selecting KCs. While tracking the total number of KCs identified to-date is informative, managers must use the data judicially, since there are generally no "good" or "bad" trends or criteria and numerical goals are meaningless. Typically, early in a program, the number of KCs should be expected to rise as new KCs are identified; later in development they should be slightly reduced as some are designed away. However, those who compile data for the metric can be inundated with requests to needlessly explain every change from reporting period to reporting period.

7.5.5 Key Characteristics and Processes Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval to Begin Program):

Milestone II (Approval to Enter EMD):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section. Ongoing access to information about KCs should take place as necessary within day-to-day IPT activities.

Instructions to Offerors Guidance (Section L)

7.6 Variability Reduction

7.6.1 Introduction

Variability Reduction (VR) is a systematic approach to improve product performance, reliability, cost, and manufacturing span times by reducing variation in key product characteristics and the processes that create them. It is based on well-known quality management principles: the focus on processes, continuous improvement, and the use of data and facts to make decisions.

VR efforts during development are intended to lay the foundation for continuous improvement in product quality during the production phase. VR activities that should be undertaken in development are: (1) develop control plans for critical processes; (2) begin data collection on key processes to determine process capabilities; (3) feed these capabilities back to the designers; and (4) implement improvements in the design and/or manufacturing processes, as required.

7.6.2 Variability Reduction Rationale

VR is based on the concept that simply attaining specification limits (also known as a "goal-post mentality") is not the best measure of quality. Rather, the degree of variability inherent in a key process and its relationship to design limits (process capability) becomes a measure of merit. According to the Taguchi Loss Function (shown in Figure 7-4), any deviation of one of a product's principle functional characteristics from nominal results in a loss to society. For defense acquisition programs, this loss to society can be defined in terms of either performance degradations or increases in Life Cycle Costs. The further away from nominal, the higher the loss. The logical solution, therefore, is to reduce the amount of variability by centering the process output as tightly as possible around the nominal specification value.

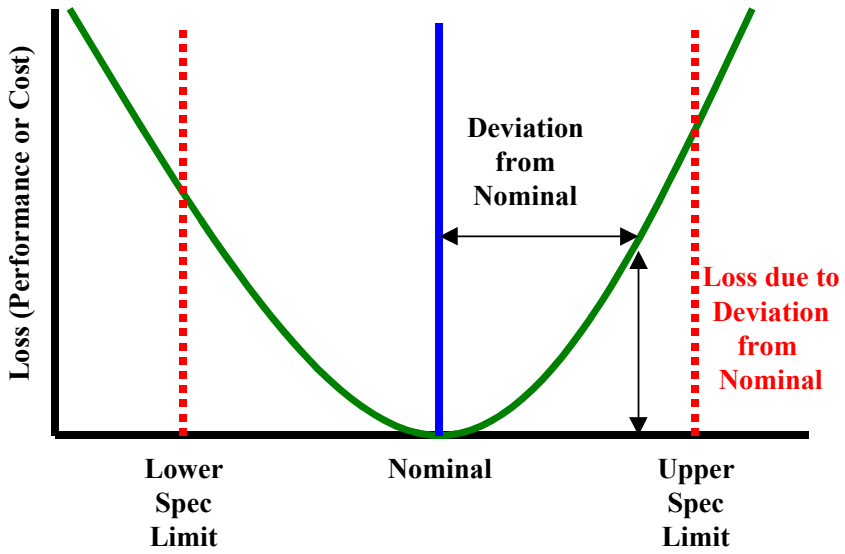


Figure 7-4. The Taguchi Loss Function

By reducing and controlling hardware variability, the customers and suppliers can realize many benefits, including:

- Quality improvement in the form of better fit, performance, and reliability
- Cost savings from reduced assembly hours
- Cost reduction due to reduced scrap, rework, and repair
- Better design decisions made possible by the engineer's knowledge of the factory's process capabilities
- Reduced reliance on end-item inspections to detect nonconformances
- Customer satisfaction due to increased service life

7.6.3 Variability Reduction Guidance

Figure 7.5 shows the sequence of activities for a Variability Reduction Program.

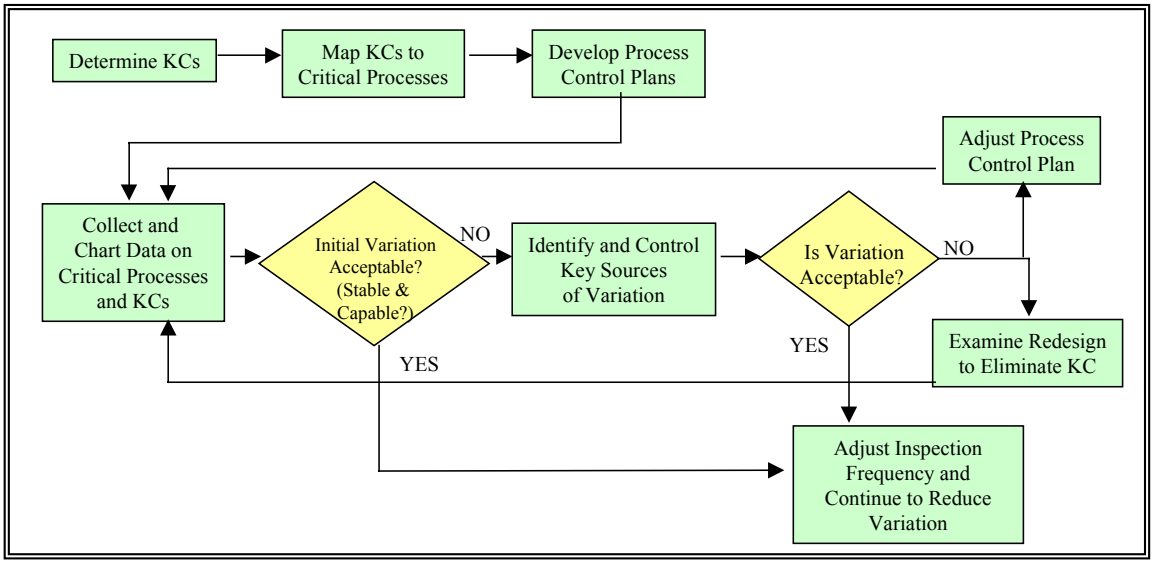


Figure 7-5. VR General Approach

Determine KCs: Two aspects of variability reduction affect the design of characteristics that have been identified as key. First, initial design tolerances should reflect process capability limitations. Data from similar parts and processes can be used to give designers guidance on the tolerances they can reasonably expect the manufacturing organization to consistently attain without significant improvements to production processes and equipment. This process capability data may be collected in databases, automated tools, or design handbooks. Second, if indications are that manufacturing can not reliably reproduce a proposed KC, the designers should try to eliminate that feature or, at a minimum, make it more robust and less sensitive to variation. These design modifications are nearly always less expensive than the two alternatives: upgrading the factory or accepting the cost of poor quality.

Develop Process Control Plans: For each critical process related to a KC, the contractor should document plans to control the process to assure KC variation is, at a minimum, within spec, and as a

goal, reduced as much as feasible. These process plans may cover multiple KCs, since a single process may produce more than one key characteristic. The amount and type of documentation depends on the complexity of the characteristic and the process. The control plan should always include a brief explanation of the KC, what data will be collected, where in the process it will be collected, how it will be collected, and how it will be analyzed (types of charting and who will analyze it). Additional content will vary with the type of key characteristic. Process control plans should be considered dynamic and the IPT should adjust them periodically to account for changes in process capability.

Collect and Chart Data: Data should be collected in accordance with the process control plan. Early in development when few items are produced, short-run techniques must be used to analyze data to make statistically significant observations. One option is to use data from other products produced using the same process. Numerous industry sources are available to assist in the collection and analysis of limited data.

Is the Initial Variation Acceptable? To determine acceptability, the process capability index (Cpk) must first be calculated using the following formula:

Cpk = Minimum [USL-Avg, Avg-LSL] / (3σ)

Where:

USL = Upper Specification Limit

LSL = Lower Specification Limit

Avg = process mean

3σ = 3 times the process standard deviation

Note: The above formula and the following discussions are based on the assumption that the characteristic has an optimum value with specification limits on either side. For cases with a one-sided tolerance (roundness of a bearing, for example, where "0.0" out-of-round is optimal and there is a maximum allowable deviation from "0.0"), please refer to statistical texts for analysis assistance.

Higher C_{pk} values indicate a more capable process, with a C_{pk} of 1.0 indicating that the process has either its upper 3-sigma variation or its lower 3-sigma variation at the specification limit, as shown in Figure 7-6. A C_{pk} of 1.5 is equivalent to 6.8 defects per million opportunities, and represents a commonly encountered VR standard. A C_{pk} of less than 1.00 corresponds to a defect rate of greater than three per thousand. It is usually indicative of an immature or incapable process that requires additional development, a design change, or added process verifications to assure conforming product is delivered. Acceptability should be determined by the IPT and be based on producibility, cost, and quality considerations.

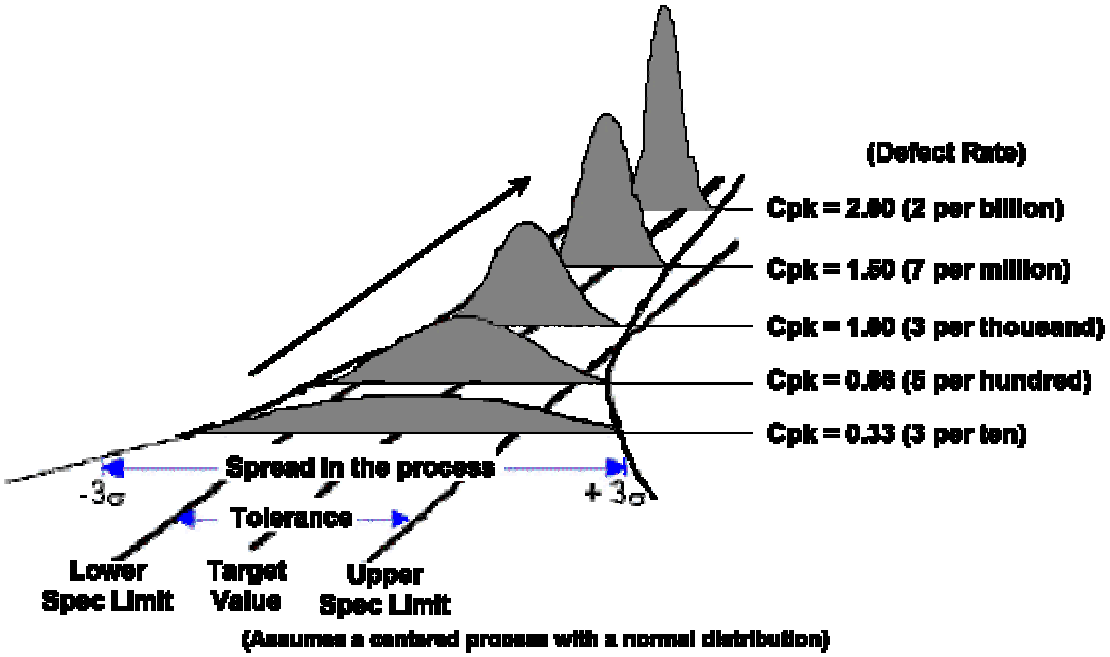


Figure 7-6. Capability Index

Adjust Inspection Frequency: If process variation is acceptable, inspections may be reduced. Certified operators may be allowed to rely on Statistical Process Control charting to monitor and accept products and to assure that no major shifts in the process occur. The quality organization may need only audit the SPC data collection process and/or sample the final product to assure the process control plans are effective.

Identify and Control Key Sources of Variation: If initial variation is not acceptable, the team must identify the sources of variation, both the common and special causes. Special cause variation is variation that is not inherent to a process, is due to some outside (often controllable) influence, and is usually detected by its predictable, nonrandom frequency. It may include variation introduced by tooling, machine programming, drill bit wear, etc. These special causes must first be removed to determine the true expected output of the process. The remaining variation is termed common cause variation and results from causes inherent to the process. Its frequency of occurrence is unpredictable and random. These cannot usually be eliminated without a major change to the process (such as by the installation of humidity controls in a humid environment). Whether variation in a process is special cause or common, it is necessary to gain a complete understanding of the process itself in order to identify and control sources of variation. For this reason, many variability reduction methodologies include process flowcharting and a detailed analysis of inputs, outputs, and controls for each process step. The flowchart, and the detailed data associated with it, serves as a starting point for identifying and controlling sources of special cause variation. Common cause variation can lead to modifications to the process and flowcharting these process improvements before implementing them increases the probability they will be successful without introducing unexpected side-effects.

Is Variation Acceptable? If the variation is still not acceptable after special causes have been eliminated and common causes controlled to the extent possible, other measures must be taken. In some cases, it might not be economically feasible to reduce variation by changing the production process. The

following are some options:

Examine Redesign to Eliminate KC: The preferred option is to redesign the product to eliminate the sensitivity of the design to the key characteristic; the characteristic may still exist, but the design is more robust so that it is no longer critical. Another option, if performance allows, is to open the design tolerances on the characteristic. By definition, this will improve the process capability index (Cpk). This is the same option discussed in the "Determine KCs" paragraph above. Redesigning to open tolerances is a first option considered while the design is in development and a last option after we've tried everything else to make an existing process capable. This measure may also require changes to interfacing parts or relaxation of requirements.

Adjust Process Control Plan: If process variation is still not acceptable, additional controls may have to be added (such as inspection) to assure that only conforming product is delivered to the next step in the process. However, many years of experience with inspection have shown that it is not a perfect solution. Most inspection is still performed by humans, who have a limited capability. If every item is inspected, there is still a probability that some unacceptable product will be accepted. The best solution is to avoid production of unacceptable product.

7.6.4 Variability Reduction Lessons Learned

It is easy to lose the focus on processes and instead focus on product. Since key characteristics are naturally product related, there is a tendency to gather data on a part number by part number basis, losing sight of the fact that similar KCs on different parts may have been created with the same process.

Metrics can be an extremely contentious issue. First, it is difficult to distill down a usually voluminous and complex amount of data into a simple, easily understood chart. Much of the data may also originate from organizations and companies with different levels of understandings and different approaches to implementing VR. VR metrics can also be easily misinterpreted by those not familiar with statistical terms. For example, if a process is reported as "statistically not capable," it may have a Cpk slightly under 1.0, but can still have a yield of nearly 99%. Additional process controls may also be in place to assure conforming product. However, metrics are extremely important to assess the overall progress towards achieving process maturity and capability.

Although there are almost as many ways to do Variability Reduction as there are contractors and subcontractors, the principles of each methodology should germinate from the goal to reduce quality cost and the philosophy of continuous improvement. Rigidly applying a methodology and generating and displaying SPC charts without a good understanding of the nature of the variability you are trying to control will be less than successful. For this reason, question anyone who wants to prove their Variability Reduction program is successful by showing a stack of charts. The true measure of success is results (fewer rejects, lower cost) and the only way to attain this is to understand the production process.

The statistical analysis of production data has been facilitated by many time and labor saving devices developed over the last few years. Most are in the form of computer software that does the necessary calculations for you. While these tools bring a powerful capability to the uninitiated for garnering meaning from raw data, they also bring an unlimited opportunity for misapplication and confusion. Don't assume that because a computer statistical package can take some data and give you an answer, that it is the right answer. There is one statistical principle that needs to be honored: Don't use data that

you don't understand (Where did it come from? Is it normally distributed?)

7.6.5 Variability Reduction Recommended RFP / Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval to Begin Program):

Milestone II (Approval to Enter EMD):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions To Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

7.7 Virtual Manufacturing

7.7.1 Introduction

Virtual manufacturing is an integrated, synthetic (computer generated, not real) manufacturing approach. It uses modeling and simulation to address the properties and interactions among the materials, production processes, tooling, facilities, and personnel involved in a new product's design and manufacture *before* the product and process designs are released while changes can still be made in a cost effective manner. In traditional product development approaches, by contrast, decisions made during the Concept Exploration (CE) and Product Definition and Risk Reduction (PDRR) phases have often locked 65% to 75% of the cost into the product, and have proven difficult or extremely expensive to change later. Ideally, virtual manufacturing is used initially during Concept Exploration (CE) to evaluate the producibility and affordability of proposed design concepts, and continues to be used and refined providing ever increasing fidelity as the system design evolves through the EMD phase and into the Production phase.

Virtual Manufacturing also plays a role in the concept of the "Virtual Enterprise." In a Virtual Enterprise, critical manufacturing related information is communicated across barriers between organizations (business to business). A Virtual Enterprise consists of any number of geographically separate but virtually collocated teams of companies and government organizations, representing the best world-wide capabilities available at the time, independent of organizational affiliation, working together electronically at least as efficiently as a fully collocated team within one company or organization. If this Virtual Enterprise has a manufacturing element to its operation it will likely be virtual as well. The simulated capabilities of a particular supplier's production processes can influence the design regardless of the distance separating the system designer and manufacturer. The manufacturer has the same advantages regarding easy access to the designer during production.

Regardless of physical distance between the cooperating entities, virtual manufacturing allows for the ultimate efficiency possible in all production phases, including selection of sources, development of Numerical Control data, fabrication of components, assembly of systems, and delivery of products.

Product design iterations in a virtual manufacturing environment are often possible at a much lower cost and on significantly more accelerated schedules than in a physical environment. For these reasons, virtual manufacturing is becoming an increasingly common alternative or supplement to traditional means of demonstrating factory capabilities, such as Line Proofing. (See Product and Process Validation.) Like line proofing, virtual manufacturing supports risk management activities by verifying and validating the capabilities of the production facilities. Unlike line proofing, virtual manufacturing does not require actual production tooling and a first set of parts since it builds virtual rather than actual products or product components.

Manufacturing simulation tools like Variation Simulation Analysis (VSA) are used to identify sources of variation in the production processes and to predict production yields. By simulating the production of 100 or more parts to a specified design tolerance given known production limitations, production yields can be accurately predicted early in the design process, months before metal is machined and hardware is produced. In this way, the designer can identify limitations to the producibility of the design early in the development process, when it can be fixed more cheaply.

Stereolithography is another rapid prototyping tool which can provide subscale or full-scale physical model visualizations directly from CAD designs (and can allow assembly process demonstrations early in the design process). It provides some of the benefits of simulation at a lower cost. Stereolithography has the added advantage of producing prototype parts directly from the 3-dimensional model design, in a fashion similar to the method Computer Aided Manufacturing will use to produce the actual part.

Virtual manufacturing approaches also enable the manufacturing engineer to effectively demonstrate manufacturing issues to the IPT. Because virtual manufacturing and virtual prototyping capabilities allow the integrated product team to validate its product design and production processes in a synthetic environment, the IPT can evaluate the performance characteristics of a greater variety of product configurations and make truly effective cost and performance trades at the earliest stages of development. The result is an initial production unit that meets performance objectives with almost no rework and at the lowest possible cost.

7.7.2 Virtual Manufacturing Rationale

The virtual manufacturing and virtual prototyping process includes new tools for assembly simulation, process flow simulation, and numerically controlled machine tool simulation. These are integrated with CAD tools, MRP, scheduling tools, time standards, work instructions, and planning. Virtual manufacturing activity starts with the development of a virtual prototype, and continues through the design and first unit planning phases to create a digital manufacturing plan. Addressing issues from plant layout to the supplier base, the digital manufacturing plan provides a solid foundation for manufacturing control protocols.

The benefits of virtual manufacturing include:

- Ability to quickly evolve the pre-EMD product and process design in a synthetic environment where changes can be made early and cost effectively.

- Ability to increase design iterations while decreasing physical iterations.
- Improved communication and cohesion between Integrated Product Team participants during product development, with virtual design and virtual manufacturing models as a common visual reference point.
- Assurance of optimum first time results for prototypes.
- Optimized manufacturing planning and cost estimating.
- Enhanced LRIP efficiency and facilitates ramp up to full production.
- Reduced risk of transition to production.
- Reduced unit cost through the avoidance of rework.
- Reduced T_1 labor costs.
- Reduced sustaining engineering effort.
- Reducing production cycle time and verification of production tooling concepts.
- Producing simulations that are reusable for developing operator work instructions and maintenance tasks.

Virtual manufacturing makes it possible to effectively realize the full benefits of Integrated Product Development and manufacturing's early involvement to influence design quality, producibility, and affordability. The advent of virtual manufacturing and its linkage to the design model has made it easier for the manufacturing engineer to decipher the true impact of each design iteration, and to get his message across to other members of the design team. Now manufacturing engineering can be fully integrated into the product design effort with virtual tools that help identify and explain the impacts of the design on producibility using data and visual models that will be understood outside the manufacturing arena.

7.7.3 Virtual Manufacturing Guidance

The contractor should use virtual manufacturing tools to demonstrate that the product design developed during the pre-EMD efforts meets the cost and schedule objectives of the program. This is best accomplished through preliminary production planning, which includes assembly simulation and process flow simulation, utilizing the processes required for fabrication. On the contractor's side, these efforts are frequently led by the manufacturing engineering function during the pre-EMD phases. The contractor should also demonstrate the producibility of the proposed design through the use of virtual prototyping and virtual assembly, including 3D simulation of assembly for both the product and its proposed tooling. This permits production cost and schedule risks tied to the design to be qualified as soon as design options are developed and before resources are committed.

Process flow simulation should identify the production resources required, including personnel skills, tool quantities, production space requirements, inventory levels, and resource constraints. This effort will serve to validate cost estimates and proposed schedule performance. It will also identify issues associated with material availability or new process development. The simulation tools thus provide a

quantitative and analytical basis for the participation of the manufacturing engineer in the IPT process.

7.7.4 Virtual Manufacturing Lessons Learned

The ability to assess manufacturing capabilities in a synthetic environment early in the design process has contributed to lower total costs, reduced technical and schedule risk in the transition to production, and increased confidence that programs can meet affordability targets. The effectiveness of the early implementation of virtual manufacturing was demonstrated on a major commercial aircraft program, which reported a 90% reduction in error related changes after the release of the product design.

Other companies employing virtual manufacturing processes for assembly simulation or visualization and process flow simulation report reduced total costs attributed to the schedule benefits and manpower savings associated with getting the design correct the first time. The combination of virtual manufacturing and integrated design and analysis tools already being developed and integrated by aerospace contractors has demonstrated significant savings potential in comparison to traditional approaches.

A program to redesign an existing C-17 bulkhead, for instance, demonstrated the benefits of virtual manufacturing by comparing results to those of parallel activities using IPPD practices without VM. The design cycle time was reduced by 33%, and design cost was reduced by 27%. Another program, this one contractor funded, used solid modeling, parametric design, and virtual manufacturing tools to redesign a T-45 tail stabilator. EMD phase savings of 28% were achieved in comparison to the lower of two competitive bids using conventional design approaches.

In general, the application of IPPD approaches and other affordability initiatives on recent programs has been shown to produce reductions in EMD costs that range from more than 10% to as much as 25%. (EMD costs typically represent 12% of life cycle costs on a weapon system development program.)

The ability to approach or exceed the benefits achieved in the preceding examples depends largely on two factors: the phase of the program in which the virtual manufacturing effort is initiated, and the consideration given to a system wide application of the virtual manufacturing CAD/CAM tools. All of the examples provided are for implementation during some intermediate step in the development process. It is expected that when these tools are applied to their maximum capability pre-EMD, as is the case with programs like JSF, the savings should be even more remarkable. Until recently, it was common belief that there would not be a sufficient payback to develop the data for virtual manufacturing after a program has completed preliminary design. This assumption has recently been disproved on C-17 and other Boeing commercial and military programs. The application of virtual manufacturing to an entire system, and the processes that go into producing it, is also critical to gaining maximum leverage. In many of the examples provided, the application of one or more virtual manufacturing tool resulted in little near term payback, until the application was expanded to include down-stream organizations that could make use of the data to improve their efficiency. It is recommended that a global view be taken when implementing virtual manufacturing, and proper consideration be given to commonality of tools across an enterprise, such as portability of software and data.

7.7.5 Virtual Manufacturing Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program):

Milestone II (Approval To Enter EMD):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions To Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

Manufacturing Development Guide

Chapter 8: EMD PHASE GUIDELINES

8.1 Introduction

During Engineering and Manufacturing Development (EMD), the MDG objectives are best met by involving the manufacturing, industrial, test, and quality engineering disciplines directly in the product design activities, particularly as a principal contributor to the cost/performance trades and manufacturing risk management processes. During this period, the manufacturing engineers will characterize key processes and analyze their capability.

To ensure that affordability and manufacturing issues are fully addressed during the acquisition process, government personnel at the System Program Office (SPO) may wish to use the Recommended RFP Proposal Content sections for each practice discussed in this chapter to generate RFPs and evaluate contractor responses. Contractors, in turn, should be encouraged to review the contents of the MDG for guidance in preparing the affordability and manufacturing sections of their proposals.

8.1.1 Suggested EMD Statement of Objectives (SOO) Content

8.2 Production Cost Modeling

8.2.1 Introduction

This practice describes a Production Cost Model (PCM) which can be used to estimate the projected production cost of the proposed design against a threshold value for affordability. The PCM must address all design driven cost elements and be updated to stay current with the evolving product design and production plans. This model will have three major attributes: (1) the ability to be used in design trades to assess the cost impacts of specific design changes, alternative production processes or process improvements; (2) the ability to accumulate and assess design-related costs (as implemented in the factory) in a statistical manner and define most probable costs; and (3) the ability to support Finance and Contracting processes (such as independent program estimates and proposal preparation, factfinding, and negotiations.)

The core elements of this practice will be found in the sections on the System Specification, the Integrated Master Plan (IMP) milestone exit criteria, and the Instructions to Offerors (ITO). The tasks associated with Production Cost Modeling will be closely related to the tasks for the design trade study activities discussed in Chapter 8, Section 8.3, Design Trade Studies, and other systems engineering tasks. The proposed IMP milestone exit criteria will also be linked closely to the overall systems engineering effort.

8.2.2 Production Cost Modeling Rationale

The need for a PCM during Engineering and Manufacturing Development (EMD) is driven not only by the increasing importance of affordability in weapon system acquisitions, but also by the need to

improve Department of Defense (DoD) and defense industry performance in predicting and meeting cost and schedule requirements. Cost as an Independent Variable (CAIV) and other acquisition reform initiatives are being employed to reach this objective. The ability to balance cost, performance and schedule is an integral part of the Integrated Product and Process Development (IPPD) concept (see Chapter 3, Acquisition Strategy), but to balance cost, a cost requirement must be defined and must play an equal role in the systems engineering trade process. The establishment of a Production Cost Requirement (PCR) in the System Specification facilitates this effort. Production Cost Modeling enables evaluation of the product design cost estimates against the PCR in the System Specification, and permits realistic and timely cost/performance trade studies.

8.2.3 Production Cost Modeling Guidance

The intent of Production Cost Modeling is to provide a tool for predicting and controlling design driven production cost. This includes the facilities and equipment required to implement the selected production processes. This activity may also be used as a comprehensive cost model which takes into account indirect costs not controlled by the design (such as impacts of the overall business base). The specific cost components of the model must be sufficiently documented to provide an audit trail for subsequent adjustments.

For the contractor to develop a valid cost model, the government must define specific parameters to be used as assumptions in the model. These include variables such as constant versus then year dollars, production volume and rates, and any fiscal year budget constraints. The production volume and rates are important in defining the return on investment for capital equipment costs and other potential manufacturing investments which have a strong influence on product design. To avoid a "point" design solution, the production rates and volumes may be defined as ranges with the target rate identified. With few exceptions, the rate, volume, and other assumptions have a significant impact on the final design and production cost. The assumptions must be as realistic as possible and the rate/volume ranges as narrow as possible. Many commercial cost models are available for use and/or adaptation to fit company-unique accounting systems. The level of detail and the complexity of the cost models appropriate for a product will vary depending on the product's complexity, program size, and other factors.

Life Cycle Cost (LCC) defines true system affordability, but is difficult to predict with confidence during EMD. Therefore, a PCR is recommended as a more verifiable cost element. When combined with development cost, the PCR provides the baseline cost against which design trades can be evaluated in the implementation of CAIV. Support cost is no less important, but there are a number of other product performance requirements (such as reliability, maintainability, and availability) which can be used as metrics for assessing progress in controlling support cost. The cost element to be controlled should be selected to satisfy specific program requirements, and may be, for example, Flyaway, Weapon System, Procurement, or Program Acquisition cost.

In most cases, it will be important to account for Special Tooling (ST), Special Test Equipment (STE), and Support Equipment (SE). Warranty costs should also be considered. The actual selection of the cost definition must be made for individual programs to control those costs considered most important. Cost requirements should consider both Government Furnished Property (GFP) and Contractor Furnished Property (CFP). It is also appropriate to include sustaining engineering and rate tooling in the requirement if these are likely to be cost drivers. It is essential that program assumptions and basic definitions used in establishing the PCR be made available to the contractor for inclusion in the PCM.

Any changes to those assumptions must be flowed down to the contractor for inclusion in updates to the PCM.

Cost analyses will be based on the most current hardware and software configuration using the procedures and assumptions established for PCM. Current production cost estimates should be available to support Technical Interchange Meetings (TIMs), Program Management Reviews (PMRs), major milestone reviews, yearly contract negotiations, and formal design reviews and technical audits. The primary use of the PCM in the EMD phase is to verify that the most probable cost of the applicable cost elements is equal to or less than the cost requirement stated in the System Specification. Recognizing that the intent is to define most probable cost, and that the ability to model production cost accurately at the start of EMD is virtually impossible, there will always be an uncertainty interval associated with the resultant estimate. This uncertainty interval will be relatively large early in the EMD phase, but should continuously shrink as the design and process capabilities solidify. Properly utilized, the PCM should play a significant role in the overall risk management effort.

As a goal, the contractor and the government should make the development and maintenance of the PCM a joint effort. Over time, organizations have approached this from two extremes, some with the contractor exercising total ownership over the model, others with both the contractor and government each running their own independent models. A single model, jointly agreed upon, provides the best path and engenders a close, teaming relationship. A single model gives both the government and contractor a common understanding and language with which to evaluate potential design and programmatic changes. It also facilitates contracting processes, such as negotiations of yearly lot buys.

The PCM will be developed using procedures and assumptions that have been agreed to by the Government and the contractor, with the agreement representing the "validation" of the cost model. Any appropriate analysis procedure may be used in developing the PCM (parametric, historical, analogy, or detailed engineering estimates) depending on data availability and the maturity of candidate designs. The completed cost model must contain the appropriate data and relationships and be updated to reflect program status changes. The PCM should include factors that account for inspection, test, scrap, and rework if applicable. Once determined to be a reasonably accurate predictor of production cost and the relative cost impact of design changes, the PCM may be used for the final verification of design compliance with the System Specification cost requirement. When government data is needed for this analysis, the contractor will acquire it through the government contracting activity.

Cost elements included in the PCM must be clearly identified to preclude any misunderstanding, and must accurately reflect those assumptions and definitions used in establishing the PCR in the System Specification.

8.2.4 Production Cost Modeling Lessons Learned

Past experiences with acquisition cost management have been generally unsatisfactory. Typically, Design To Cost (DTC) goals, rather than requirements, have been used, and the effort has usually tended to be a bookkeeping exercise in which, at best, an estimate of production cost was tracked and compared to the "goal." In many cases, the ground rules and assumptions became invalid due to numerous program changes (such as changes in production volume or rate, or schedule slips), but little effort was made to maintain a truly valid estimate. This led to significant surprises in a number of programs when initial production contracts were negotiated.

8.2.5 Production Cost Modeling Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

Interim Event (corresponding to historical Critical Design Review):

Interim Event (corresponding to historical System Verification Review):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section

Instructions To Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

8.3 Design Trade Studies

8.3.1 Introduction

The role of design trade studies in the manufacturing development process is to achieve a product design that effectively balances the system design with cost, schedule and performance elements to minimize program risk. Any system design concept, or production concept, will have risks associated with its development or implementation. Design and production risks often relate to the producibility, supportability, and maintainability attributes of the system. Design trade studies provide a systematic way to mitigate risks that cannot be eliminated.

Trades involve iterative comparisons of cost and performance of alternatives not simply a single trade analysis on initial performance requirements. There is rarely a single point solution, so trade studies should continue throughout system development, production and support. Systems engineering can be generalized as a series of processes where design trade studies are routinely performed resulting in iterative design improvements. During Requirements Analysis, requirements are traded against each other, and against cost. Later, in Functional Allocation, functions are balanced against interface requirements and performance. In Design Synthesis, alternate solutions are evaluated to optimize cost, schedule, performance and risk (i.e. trading off the performance benefit of using high temperature materials against added cost and producibility risk.) The systems engineering trade study process employed should utilize a coordinated production cost model wherever possible, and trade studies must be part of the corporate design policy and process.

8.3.2 Design Trade Studies Rationale

Institutionalizing producibility and supportability as part of the systems engineering design trade study process is essential to an overall goal of affordable weapon system acquisition. The development of a

reliable production cost model (Chapters 7 and 8, Sections 7.2 and 8.2, "Production Cost Modeling"), and manufacturing engineering participation in the design Integrated Product Team (IPT) make it possible to use the Production Cost Requirement (normally either the AUPP or DTUPC) as the primary design trade parameter. All design trade considerations can be restated in terms of their impact on unit price. Acquisition reform has expanded the options available to design and manufacturing engineers. The freedom to use commercial or contractor-defined and controlled processes gives the designer the flexibility to propose a system design that takes maximum advantage of the most appropriate capabilities. The potential for trading cost versus performance makes the benefits of Commercial-off-the-Shelf (COTS) products more attractive to the design team. Another key element of the design trade study practice is the participation of both the government customer and key suppliers in the product IPTs and the trade study process. This involvement assures a fully integrated design effort more apt to meet customer's needs, including producibility and supportability, and one which minimizes life cycle cost. Improved communications between engineering and manufacturing personnel and between prime contractor and suppliers help to reduce integration problems that compromise system performance or which results in redesign of one or more components.

8.3.3 Design Trade Studies Guidance

Careful consideration of producibility and supportability is key to the Integrated Product and Process Development (IPPD) concept. The design trade study process should identify alternative production processes and consider the economic impacts of each alternative. Tools such as Taguchi Loss Function, Design of Experiments (DOE) or Quality Function Deployment (QFD) methods, are valuable in evaluating the viability of design alternatives. The design trades should strive for robust product designs tolerant to variation in the intended manufacturing, assembly, test, and usage environments. They should be capable of identifying the design that represents minimum life cycle cost within program constraints. When key suppliers act as full members of the design team, the functional allocation and integration of all system components is enhanced.

The effectiveness of design trade studies depends on an accurate description of the problem prompting the study, and the establishment of specific criteria for making a decision. Trade studies should be conducted to assess the producibility of **as many** design concepts as time and cost allows, with level of detail and accuracy dependant on the relative contribution of each concept to achieving the Production Cost Requirement (see figure 8-1 below). The introduction of new technology can also introduce new design challenges. Utilizing concepts unproven in a production environment may result in severe cost and schedule problems. Environmental limitations must be addressed when analyzing alternatives. The benefits of utilizing commercial parts and processes and the affordability penalties resulting from the use of non-standard parts and processes should also be evaluated and documented in design trade-off decisions.

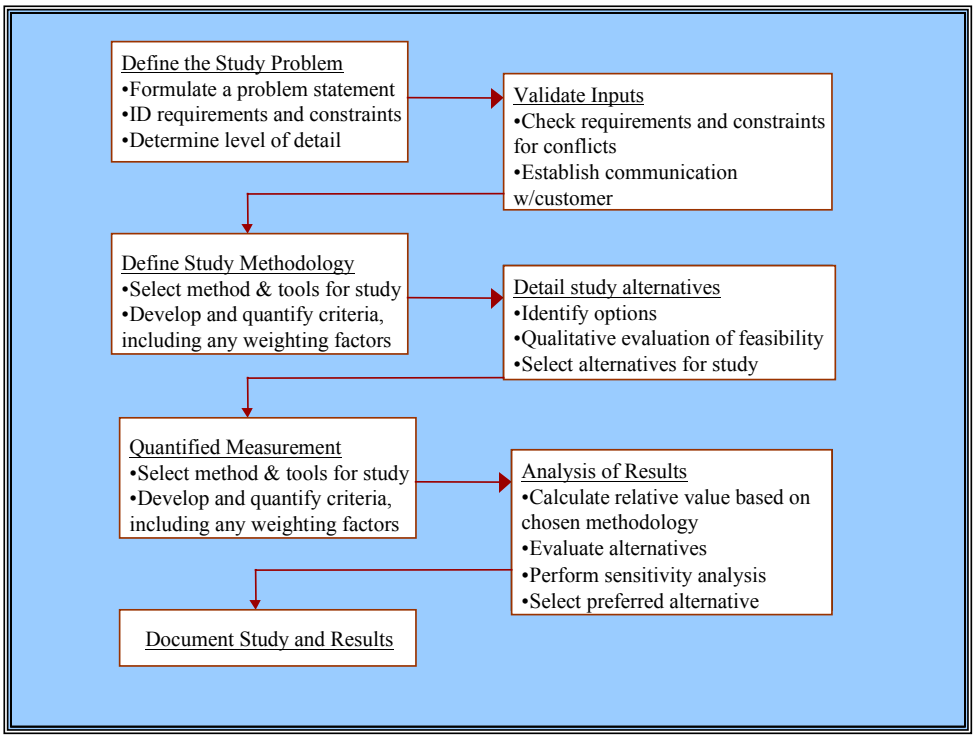


Figure 8-1 Trade Study Process

There is considerable flexibility regarding the level of detail reached in a trade study, with the degree of cost and schedule risk a controlling factor. Since the analysis is time-critical, ensure that design trade study procedures establish a specific schedule for completion, identify individuals responsible, and define a proper level of reporting prior to Critical Design Reviews.

Trade studies should encompass the product design, production processes, Special Tooling, Special Test Equipment, and Support Equipment (ST/STE/SE). Mandated performance requirements ("must haves") provided in the System Specification form the baseline. However, design margins should still be identified for each of the items in the System Specification. The contractor should have the flexibility to address how much margin is applied within program cost and schedule constraints. Additional capabilities above the individual requirements may be found within the total system constraints, and the contractor should be encouraged to identify opportunities for improved capabilities. Two areas addressed in the Design Trade Study process are the impacts on system performance and cost (both production and life cycle cost) from the use of COTS and non-standard parts and processes. The affordability aspect of COTS and non-standard parts and processes must, in particular, be evaluated with respect to life cycle cost considerations such as maintainability and reliability.

This practice deals primarily with the effort leading to the design of the product and ST/STE/SE. There are seven central elements to this effort:

1. Establishment of specific criteria acceptable to all members of the integrated design team to be used as a basis for decision.

2. Flowdown of the requirement to perform design trade studies, and participation of key suppliers in the design IPTs.

3. Integration of trade study efforts into the Integrated Master Plan (IMP) with identification of contractor's key events supporting the IMP milestones.

4. Completion and documentation of trade studies which result in the product and ST/STE/SE designs.

5. Presentation of the status of the trade studies and rationale for utilization of the trade study results at key events and IMP Milestones.

6. Performance of risk assessments and implementation of risk management efforts.

7. Identification of opportunities for additional product / process improvement which may exceed existing program constraints of cost and/or schedule, but which could provide significant long-term benefits to system cost, schedule, and/or performance.

One common and widely accepted method of evaluation of trade studies is described here as an example. Further detail, and descriptions of other techniques, can be found in Systems Engineering guides, such as Systems Engineering Fundamentals published by DSMC, available at http://www.dsmc.dsm.mil/pubs/gdbks/sys_eng_fund.htm.

8.3.3.1 Utility Curve Methodology

The Utility Curve Methodology is a technique commonly used by DoD and industry to analyze trade alternatives. It is also used in a modified form for proposal evaluation.

A Utility Curve is established for each performance factor, showing the relative value for each factor throughout its range (see figure 8-2 below).

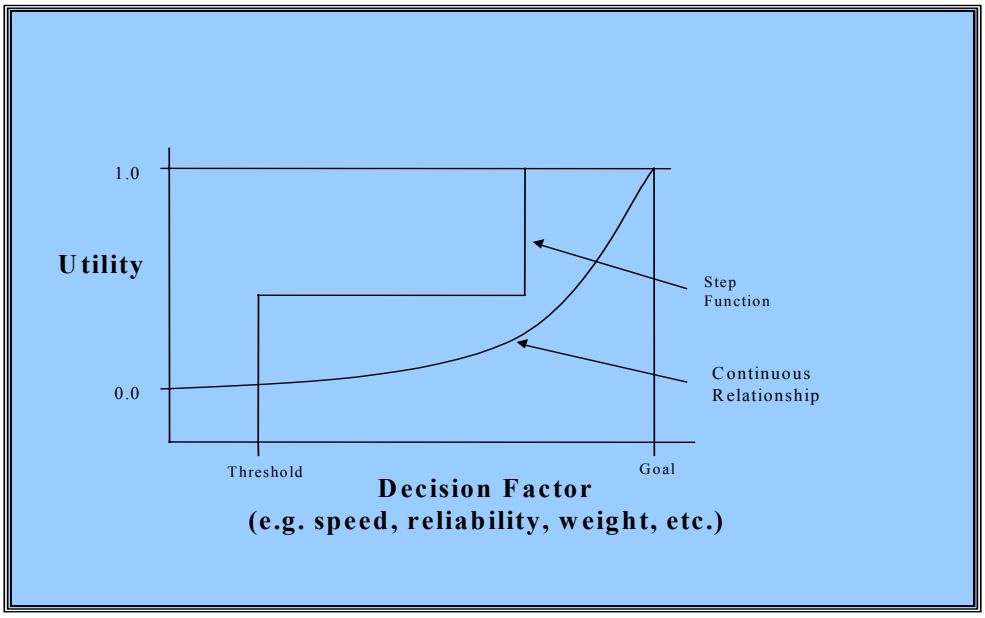


Figure 8-2 Sample Utility Curve

By normalizing all factors on a zero-to-one utility scale, it is easier to make a comparison. The relative

value of the performance factors are reflected in a “Decision Matrix” where each performance factor is given a weighting factor. Combining the weight factor and the performance factor utility score gives the relative “value” for each factor under each alternative. Adding the values for an alternative’s factors will give a total performance score, which is comparable to the scores of all other alternatives. The winning alternative is the one with the highest total score (see figure 8-3 for a sample decision matrix).

Decision Factors / Alternatives	Range (Wt=2.0)		Speed (Wt=1.0)		Payload(Wt=2.5)		Weighted Total
	U	W	U	W	U	W	
System Option 1	.8	1.6	.7	.7	.6	1.5	3.8
System Option 2	.7	1.4	.9	.9	.4	1.0	3.3
System Option 3	.6	1.2	.7	.7	.8	2.0	3.9 ☆
System Option 4	.5	1.0	.5	.5	.9	2.25	3.75
Key: U = Utility Value W = Weighted Value ☆ - Apparent winner							

Figure 8-3 Sample Decision Matrix

8.3.4 Design Trade Studies Lessons Learned

Two functions related to design trade studies have been the source of difficulties in the past: design for production, and effective communication between primes and suppliers. Past efforts have relied on a serial development effort between product and process. During pre-Production, virtually all development emphasis was placed on system performance. Once the required performance was functionally demonstrated, an attempt was made to transition the design to production. The manufacturing engineering function then tried to adapt existing processes to manufacture the "qualified" design. The result was a sub-optimal design from two respects: (1) little or no attempt was made to optimize the product design for existing process capabilities; and (2) new or improved processes received little consideration. Considering producibility and supportability earlier in the design process promises a smoother transition to production. Reaching rate production should also be easier and more efficient as processes are continuously improved.

Weapon systems’ functional allocation and initial designs have often been completed with little or no participation by key suppliers. The prime contractor/supplier relationship has been primarily controlled by product requirements defined in specifications, drawings, and interface control documents. Since suppliers frequently had little understanding of how the product was actually to be used, their design would often meet all performance requirements; yet not successfully integrate into the weapon system. The result was a series of redesigns or compromises in overall design quality. An early integration of key suppliers into the prime contractor's design team enhances the ability to transmit actual requirements and to make trades for producibility and supportability at the subsystem and component levels. The experience gained by contractor personnel (at all levels) as they participate in interface control working groups will be useful as they adapt to the operating philosophy of joint IPTs.

8.3.5 Design Trade Studies Recommended RFP / Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

Interim Event (corresponding to historical Critical Design Review):

Interim Event (corresponding to historical System Verification Review):

Contract Data Requirements List (CDRL) Guidance

For on-going single source production programs:

- Information copies of specifications and product descriptions through the Data Accession List (DAL), with delivery upon request.

For multiple source production or delayed production programs:

Option 1: Contractor maintained library

- Information copies of specifications through the DAL, with delivery upon request.

Option 2: Government maintained library

- Product Development Definitions upon completion.
- Product Design Definitions upon completion.
- Product Fabrication Definitions at Milestone III.
- Technical Data Package and Build-to Package at Milestone III.

Instructions To Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

8.4 Manufacturing Capability Assessment and Risk Management

8.4.1 Introduction

The manufacturing capability assessment and risk management effort is a structured, disciplined approach to evaluating available and forthcoming manufacturing capabilities to identify, assess, and manage risk. It applies formal risk mitigation processes from the inception of the program to provide a continuous assessment of program progress against clearly established baseline requirements. A key focus of the manufacturing capability assessment and risk management effort is to anticipate and

eliminate schedule delays, technical compromises, and cost overruns which have historically been associated with the critical period of transition from design to production in major programs. (For other key aspects of risk management, see Sections 8.2 and 8.3, Production Cost Modeling and Design Trade Studies.)

In the current Integrated Product and Process Development (IPPD) acquisition environment, Low Rate Initial Production (LRIP) is moved forward from the production phase to the EMD phase of the program. This is done to ensure an early focus on preventing manufacturing problems before they can impact production costs, as would be the case at higher production rates. The production readiness of the LRIP hardware can now be established ahead of time through incremental verification and validation of processes and process capabilities, production planning, simulation of the manufacturing process, assuring maximum use of production processes for test articles, and other efforts and assessments.

New approaches such as virtual manufacturing, virtual prototyping, and virtual assembly (see Chapter 7, Section 7.7) minimize transition difficulties. Rate build up capability can be assessed using these same approaches. The contractor is responsible for the maturity of his production capabilities. If additional development of production capabilities is required as the design evolves, the contractor should rely on incremental verification steps to validate that the required maturity has been achieved.

It is absolutely essential that manufacturing risks be fully and timely assimilated into the program's overall risk management effort. (See Chapter 7, Section 7.3 on Manufacturing Capability Assessment and Risk Management in the Concept Evaluation and PDRR phase.) In the RFP, manufacturing capability assessment and risk management issues should be integral to program management risk and systems engineering sections, since tasks such as design trade studies, production cost modeling, and the requirements verification efforts are key elements of the risk management process.

8.4.2 Manufacturing Capability Assessment and Risk Management Rationale

A manufacturing capability assessment and risk management effort that starts early and is maintained throughout the development process is a key part of the IPPD approach to weapon system acquisition. The utilization of concurrent product and process development lowers both transition risk and overall program risk by applying to the development and qualification of the production processes the same disciplined systems engineering approach used for product development.

The strengthened emphasis on concurrent process development and verification, along with the parallel design and development of Special Tooling/Special Test Equipment/Support Equipment (ST/STE/SE), introduces a significant level of new effort that must be managed in the early stages of EMD. It is vital to implement an approach to risk identification which facilitates program decision-making, develops the appropriate risk mitigation measures, and includes them in the program's Integrated Master Plan (IMP).

In addition to the careful identification and management of the risks associated with product and process development, it is essential that thorough planning for production occur early in EMD. Virtual manufacturing tools, maximum use of production processes during the build of test articles, and line proofing are measures that provide verification of producibility. The objective is to fully support Low Rate Initial Production (LRIP) at the end of EMD, and to prepare for full rate production. All resources (including manpower, facilities, plant equipment, ST, STE, and SE) scaled for the LRIP rate must be in place.

Any aspect of a development program may become a source of manufacturing risk. The selection of materials or design directions that require new production processes is one example. Processes must be proven capable of meeting all requirements in order to assure quality. With the heightened emphasis on team performance, the integration of supplier risk into the total risk management effort is essential. This includes both subcontractors and Government Furnished Property (GFP) suppliers. (While the contractor will not be responsible for the conduct of GFP supplier risk management efforts, it will be necessary to factor any risk associated with GFP into the weapon system program and adjust the IMP.)

8.4.3 Manufacturing Capability Assessment and Risk Management Guidance

The structure of the overall program risk management effort may differ from one program to another, but the essential elements will be the same. The identification and assessment of risk will be a function of the systems engineering process, with participation by all affected functions. During the design phase, this will be a significant factor in the design trade studies. During the test and verification phases, the design trade studies form the basis for assessing and resolving problems that arise in both product and process areas.

Production planning was previously the focus of a series of incremental Production Readiness Reviews (PRRs), typically begun in the Preliminary Design Review (PDR) time frame and finalized late in EMD to support the Milestone III production go-ahead decision. The MDG replaces the PRR with a more comprehensive manufacturing review function that begins at the start of EMD and continuously assesses and manages risk at both the prime contractor and supplier level. Manufacturing risk reviews and reporting should be a formal part of the Technical Interchange Meetings (TIMs) or equivalent system and subsystem reviews. The contractor assesses the completeness of the production process verification as part of the IPT process. The Program Office may tailor a Manufacturing Risk/Readiness Review (MR/RR) for the program if risk identification warrants. With the increased use of commercial-off-the-shelf (COTS) equipment projected for acquisition programs in the new environment, industrial base capacity can become a risk factor which needs to be assessed and mitigated.

Another contribution of manufacturing personnel to the risk management effort is their input to the overall program Environmental Assessment (EA). The manufacturing processes for both production and support may be responsible for a significant part of the overall environmental impact of the program. The design trade studies should address this issue as part of the overall program cost. In particular, design producibility trade-offs should emphasize avoidance of hazardous materials and processes. It is essential to address not only materials that make up the end item product but also materials used in manufacturing processes that emit volatile organic compounds into the atmosphere (an area of EPA concern) or those that are hazardous to production work force safety (an area of OSHA concern). Accordingly, a separate and continuous process for monitoring and assessing environmental implications is a key requirement.

The development of risk mitigation plans and the inclusion of these plans in the IMP are key parts of the program management effort. Close coordination among those who develop the various sections of the RFP is essential to avoid duplication of effort while ensuring that the required activities are accomplished. Contractors should be given the flexibility to implement the risk management effort efficiently within their company structured to provide appropriate insight for and receive adequate support from the government technical and management team.

8.4.4 Manufacturing Capability Assessment and Risk Management Lessons Learned

Contractors on major programs who have achieved an efficient, on-schedule exit from EMD into LRIP are typically characterized by a disciplined approach to risk management of all areas of the program, including the supplier base. From the earliest CE and PDRR stages through EMD on these programs, the areas of risk have been addressed with formal risk mitigation efforts and systematic management attention to cost and schedule issues. Parts with high manufacturing risk are identified in Pre-EMD phases. During EMD, process development and validation programs are created for these parts. The identification of Key Characteristics and related Key Processes in the Pre-EMD phases enables the IPT to focus on those processes which create risk. The government has also recognized the importance of industrial base sustainment during the down sizing of industry and promoted judicious employment of these resources on new programs.

Prior to EMD numerous trade studies are performed to support early design decisions. Given the magnitude of engineering change activity geared toward making the initial design more robust during EMD, a key EMD challenge is the need to update those early trade studies by assessing the potential effect of proposed changes on producibility.

8.4.5 Manufacturing Capability Assessment and Risk Management Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

Interim Event (corresponding to historical Critical Design Review (CDR):

Interim Event (corresponding to historical System Verification Review (SVR):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions To Offerors (ITO) Guidance (Section L)

Evaluation Criteria Guidance (Section M)

8.5 Key Suppliers

8.5.1 Introduction

A key supplier, including a supplier of Government Furnished Property (GFP), is a supplier at any level whose performance is essential to the development and production of an effective, affordable system. There are several criteria that can result in a supplier being deemed "key," such as:

- The requirements flowdown process which results in a supplier's "product characteristic" being essential to achieving the "system attribute (requirement)".
- A supplier is identified as "sole source" because of unique technologies or unique manufacturing capabilities.
- A supplier is “single source” due to limited funds or production quantities.
- Excessive risk, either in cost or technical performance, with no low-risk alternative available.

8.5.2 Key Suppliers Rationale

The percentage of work performed at the subcontractor level on weapon system programs continues to grow. Various studies have shown that once a program reaches production, supplier activities typically account for more than 60% of the total production cost. It is essential to integrate the key suppliers into program planning and development as early as possible so the program can leverage the supplier’s knowledge and experience and allow supplier participation in design trade studies, interface definition, and detailed design activities.

8.5.3 Key Suppliers Guidance

Key suppliers should be integrated early into the proposal preparation and Integrated Product and Process Development (IPPD) activities to enable the Integrated Product Team (IPT) to take full advantage of their capabilities, system, and process knowledge. Supplier tasks must be fully integrated into overall program plans and schedules and a plan developed which fully describes the supplier management effort. Successful supplier participation in the IPPD process will require effective communication of requirements and goals between the prime contractor and suppliers. It is intended that the requirements flowdown process function in a cooperative fashion between parties. The prime contractor should establish a system for key supplier selection that is based on past performance, proven abilities demonstrated on similar programs, and assessment of the capabilities of key suppliers for the chosen technologies. The system also should address supplier implementation of best practices, such as the MDG or Lean Aerospace Initiative concepts.

The use of Government Furnished Property, Equipment, Services, and Facilities (GFP) represents a special area of focus in the treatment of key suppliers. Communication and teamwork between the prime contractor and key GFP suppliers must be fostered. This will require the government to assure that contracts with key GFP suppliers and the prime contractor allow Associate Contractor Agreements (ACAs) which expedites communications in areas such as interface requirements, changes in design, risks, and schedules.

8.5.4 Key Suppliers Lessons Learned

Programs that have not successfully integrated their key suppliers have had difficulties in meeting their

requirements and goals. Past practices often neglected the supplier base until after concepts had been developed and designs begun. This has led to problems when supplier product and process capabilities were insufficient compared to predicted performance and allocated needs. System integration was often hampered by interface difficulties and the prime contractor often had little insight into supplier risk areas. Past performance data relative to suppliers was lacking or given less emphasis than cost in selection activities. Supplier lead times were optimistically factored into overall program schedules without sufficient accounting for delays. Often, GFP Contractor requirements were not kept current with the Prime Contractor's system design. Inadequate supplier risk assessment tools were available, resulting in little risk identification and little subsequent mitigation planning.

8.5.5 Key Suppliers Recommended RFP / Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

Interim Event (corresponding to historical Critical Design Review):

Interim Event (corresponding to historical System Verification Review):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

8.6 Key Characteristics and Processes

8.6.1 Introduction

For a thorough discussion on the identification of key characteristics and processes, please refer to section 7.5.

Early in EMD, the list of preliminary KCs identified in the previous phase should mature to a final list. As KC identification is finalized, the corresponding list of critical processes should also be completed.

Later in EMD, the list of KCs should be reduced as the product design is refined to make key characteristics less sensitive to variation.

8.6.2 Key Characteristics and Processes Rationale

For a discussion on rationale, please refer to section 7.5.2.

8.6.3 Key Characteristics and Processes Guidance

For a discussion of key characteristics and process guidance, please refer to section 7.5.3.

8.6.4 Key Characteristics and Processes Lessons Learned

For a discussion of key characteristics and processes lessons learned, please refer to section 7.5.4.

8.6.5 Key Characteristics and Processes Recommended RFP / Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

Interim Event (corresponding to historical Critical Design Review):

Interim Event (corresponding to historical System Verification Review):

Milestone III (Approval to Enter Production):

Contract Data Requirements List (CDRL) Guidance

- Information copies of product definitions, specifications, and Technical Data Package. This item should be made available, upon request, as informal Data Update Events (DUE)

Instructions To Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

8.7 Variability Reduction

8.7.1 Introduction

For a detailed discussion of VR, please refer to section 7.6.

As EMD progresses, more process data becomes available as developmental units are being built. This data must first be analyzed for applicability, given potential design and process changes. When the data is deemed acceptable, it can be used to gain an initial understanding of the process capabilities and should be fed back to the design engineers.

8.7.2 Variability Reduction Rationale

For a detailed discussion, please refer to section 7.6.2.

8.7.3 Variability Reduction Guidance

For a detailed discussion, please refer to section 7.6.3.

8.7.4 Variability Reduction Lessons Learned

For a detailed discussion, please refer to section 7.6.4.

8.7.5 Variability Reduction Recommended RFP / Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Critical Design Review):

Milestone III (Approval to Enter Production):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions To Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

8.8 Long Lead and Non-Recurring Activities

8.8.1 Introduction

Long lead items are defined as those components, parts, materials, and efforts whose lead-times are significantly longer than other components of the system or subsystem, and, as a result, must be funded in advance of full production program release to protect the planned production schedule.

Low Rate Initial Production (LRIP) is that work effort intended to result in completion of manufacturing development in order to ensure adequate and efficient manufacturing capability and to produce the minimum quantity necessary to provide production configured or representative articles for initial operational test and evaluation (IOT&E). LRIP may also establish an initial production base for the system and permit an orderly increase in the production rate for the system, sufficient to lead to full-rate production. LRIP has been moved forward into EMD to smooth the transition from development to production. Long lead, non-recurring activities, and other production phase issues required to support initial production (LRIP) have also moved into EMD.

Long lead, non-recurring and LRIP efforts were previously part of a separate contract or part of a production contract that was executed concurrently with the development effort. Funding came from a

separate source outside the development budget. A single contract may now be used for development, long lead/non-recurring and LRIP items, but different funds sources may still be required for each.

Long lead items create additional costs and risk for the program. Cost issues include additional contractual actions and early allocation of scarce program funds, so the number and costs of these items must be kept to a minimum. IPTs involved in planning, design and selection of components should strive to avoid the necessity for long lead expenditures. Risk issues include design stability, configuration and schedule. Long lead parts may require rework or replacements if changes are made to system design after the long lead contracts are awarded. Some parts, such as castings, have historically high lead-times. The IPT should determine if a lower cost or equal cost method of manufacturing is available. Alternate sources of manufacture should be sought if one vendor has a long queue or requires the program to lock-in a delivery schedule via long lead funding. The program assembly schedule should be reviewed to see if an alternate sequence for assembly could be developed to avoid long lead expenditures.

Integrated Product and Process Development (IPPD), a key objective in the new acquisition environment, facilitates the incremental demonstration of production process capabilities early in the development phase by maximizing the use of final production processes, equipment, tooling, and test equipment. The verification process culminates in LRIP, which now occurs at the end of the development phase.

Product and process development must begin early in product design and encompass all life cycle tooling requirements, including design and verification, for all in process and final testing. This includes Special Tooling and Special Test Equipment (ST and STE). The use of a common database for both product and production tooling reduces the risk of mismatch or incompatibility. The effective simulation of manufacturing and support equipment in the pre-EMD phases provides a baseline against which to evaluate the actual design during EMD, and simulation tools can significantly reduce tool redesign and rework.

The guidance provided in this section does not apply to the acquisition of long lead items authorized, or directed by Congress to protect production schedules.

8.8.2 Long Lead and Non-Recurring Activities Rationale

The verification of production process capabilities and the non-recurring efforts required to design, fabricate, test and deliver ST/STE for production, should be addressed in the preliminary manufacturing plan and the Integrated Master Plan (IMP). The cost of ST/STE should be an element in the design trade studies due to the cost and schedule issues that may arise if product design changes require corresponding changes to the ST/STE. LRIP success demands that all long lead orders must be placed and all traditional non-recurring activities be completed in time to acquire the materials and components needed for initial production.

The verification of SE requirements and development of the equipment is now part of the development effort and is performed concurrent with the product design to ensure the supportability of the fielded system. Process flow simulations and assembly simulations performed by the IPT's manufacturing engineering function during pre-EMD to reduce risk should be documented to support these activities.

8.8.3 Long Lead and Non-Recurring Activities Guidance

The level of effort required for long lead items and non-recurring activities will depend on the program direction and on the level of risk associated with the selected production processes. New or significantly improved production processes may require additional attention. The contractor must begin planning early for the design and acquisition of all long lead materials and ST/STE. The equipment required and the process development and maturation factors incorporated in the risk reduction manufacturing process flow simulations will be reflected in this process. The IMP should contain a requirement to establish the schedule for acquisition of all LRIP equipment and materials.

The contractor should structure the program effort to provide incremental verification of production process capabilities during EMD. LRIP should provide a final verification of production capabilities, including long lead items, and those non-recurring efforts required to design, fabricate, test, and deliver the ST/STE for production. The cost of this equipment should be considered in the design trade studies. Similarly, development and verification of SE requirements is essential to ensuring the supportability of the fielded system. Effective simulation of the process flow, with a careful focus on both production and supportability issues, should be an integral part of the contractor's Integrated Master Plan.

8.9.4 Long Lead and Non-Recurring Activities Lessons Learned

With the emphasis on reducing acquisition cycle time, the identification of long lead issues increases in importance. The program plan for LRIP must address the need to have ST/STE available. Critical items should be included in the IMP and program schedules to assure management focus. Experience with recent successful programs indicates those that effectively meet both cost and schedule objectives have done so by paying careful attention to long lead items. The use of commercial off-the-shelf products and the reuse of test equipment and software have also contributed to the success of these programs.

8.8.5 Long Lead and Non-Recurring Activities Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

Interim Event (corresponding to historical Critical Design Review):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

8.9 Product and Process Validation

8.9.1 Introduction

Today's acquisition environment emphasizes the benefits of early, incremental verifications of producibility and of production capabilities during the development phase of an acquisition program so the proper application of product and process validation in today's environment merits careful consideration. Traditionally, the line proofing process has been the preferred means of demonstrating factory capabilities, using actual production tooling and a first set of parts to build an actual product or product component late in EMD as part of the transition to production. In this manner, line proofing has served a number of important purposes: verifying the final build-to package; verifying the capability of ST/STE; testing factory operations; verifying fault detection capabilities; and providing the systems integration and test experience required to produce the end product. A structured line proofing approach was also valuable because it allowed iterative build, test, analysis, and improvement cycles to affect the design and build processes.

The rapid development of newer, more effective virtual manufacturing and assembly tools, now makes it possible to accomplish many of the product and process validation objectives once provided by line proofing earlier and cheaper. Incremental verification achieves the same objectives without expending all the resources traditionally required by the use of actual production tooling and parts. A structured approach to incremental verification, simulation-based risk reduction, and virtual manufacturing makes it possible to check and verify the entire production process and the supporting infrastructure, thus almost totally eliminating first unit rework and the classic transition, early production, and build-up problems.

Determining if a process like line proofing is called for in today's acquisition environment requires an analysis of the extent to which virtual manufacturing processes might provide a better demonstration of production capabilities, and impart cost, schedule, and performance benefits.

8.9.2 Product and Process Validation Rationale

Today's incremental verification and validation approaches require that the decision to require any form of traditional product and process validation activity such as line proofing, and the determination of the extent of such an effort, should be tied to special factors such as high production rates, innovative processes, ST/STE/SE challenges, special production transition problems, or other identified risks which call for definitive resolution in a production environment. The magnitude of the product and process validation effort, whatever form it takes, will depend on the availability of resources, the degree of risk identified, the maturity of processes, and the extent to which real or simulated production processes were employed to build test articles during EMD.

8.9.3 Product and Process Validation Guidance

The main objective of the product and process validation effort is to reduce risk by verifying both the direct and indirect infrastructure required for production prior to the start of the actual production articles. For maximum usefulness, the product and process validation line proofing effort should consider whether the LRIP/prototype/test articles were produced (or simulated) in the final production assembly area, the extent and level of success of similar production efforts at the same facility, the

extent of new or modified equipment required for production, and the stability of the infrastructure which supports production.

8.9.4 Product and Process Validation Lessons Learned

The recognition of the need for more effective risk management earlier in the acquisition program (and the development of new tools like virtual manufacturing) has changed product and process validation from an end-of-the-process scenario (where the tooling, test equipment, and product design are evaluated in an actual LRIP build) into a process which verifies and validates some items in a synthetic environment, and others incrementally throughout the design cycle. Experience with more recent programs employing MDG principles indicates that first time product success is usually a result of both synthetic and real testing of new materials, designs, and processes.

8.9.5 Product and Process Validation Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW) Content

Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

Interim Event (corresponding to historical Critical Design Review):

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions To Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

*Joint Aeronautical commanders Group (JACG) Non-government Standards Integrated Product Team (NGS-IPT) Final Report, 29 February 1996.

Manufacturing Development Guide

Chapter 9: PRODUCTION PHASE GUIDELINES

9.1 Introduction

During Production, positive outcomes, facilitated by MDG guidance, are achieved by enabling an environment of continuous improvement in product quality and production efficiency through the application of defect prevention techniques, continued supplier involvement in Integrated Product Teams (IPTs), and an effective variability reduction effort. To ensure that affordability and manufacturing issues are fully addressed during the acquisition process, government personnel at the System Program Office (SPO) may wish to use the Recommended RFP/Proposal Content sections for each practice discussed in this chapter to generate RFPs and evaluate contractor responses. Contractors, in turn, should be encouraged to review the contents of the MDG for guidance in preparing the affordability and manufacturing sections of their proposals.

9.1.1 Suggested Production Phase Statement of Objectives (SOO) Content

9.2 Manufacturing Process Control and Continuous Improvement

9.2.1 Introduction

During the production phase of a weapon system program, the responsibility of the manufacturing engineering (ME) function is to focus on the effective control of the manufacturing processes and on the orderly incorporation of improvements in both product and process. As used here, the term "continuous improvement" refers not so much to improvements themselves, as to the development and implementation of tools and techniques for continuously improving manufacturing processes. Among them:

- Identifying and implementing improvement opportunities in all process areas.
- Establishing a culture in which all employees will be constantly seeking opportunities to make improvements in the tasks they perform and in the ways they perform them.

The analysis and use of data to search for and implement improvement opportunities on a continuous basis should be an inherent part of any continuous improvement culture. Use of the Pre-Production MDG practices will permit the effective implementation of the Production phase Manufacturing Process Control and Continuous Improvement practice.

In today's acquisition environment, contracts should be structured to provide incentives for continuous production phase improvements, desired schedule performance, enhanced affordability, reduced acquisition cost, and enhanced supportability.

A number of promising concepts and effective techniques related to process control and continuous

improvement have been developed in the commercial sector and in the defense industry, including Statistical Process Control (SPC), Taguchi Loss Function, Kaizen, and Pareto Analysis. The JACG Guide on Defect Prevention Practices provides information on these and related topics. Additional information on these subjects is readily available from many sources.

9.2.2 Manufacturing Process Control and Continuous Improvement Rationale

The production phase of DoD acquisition programs has frequently been plagued by a cluster of manufacturing problems, usually with one or more of the following contributing causes:

- The lack of effective, systematic process controls during production.
- The absence of clear identification of key product features and key characteristics.
- The absence of systematic process improvement efforts.
- The lack of effective cost control.
- The absence of clear incentives for reducing costs during production.

Even when development and design are complete, significant changes may still need to be made in a weapon system program. Improvement opportunities are often still available to those who are trained to look for them. Although product and process designs developed in EMD have been demonstrated and matured in the LRIP phase, lessons learned from development testing and the initial production delivery may point to a need for significant modifications to the design. In addition, quality feedback from process areas may make other improvement needs evident. Class I changes are often approved during the Production phase, with a potential for major impacts on performance, producibility, and affordability. Although proper implementation of MDG practices should greatly reduce the need for design changes during the Production phase, some change activity is still expected.

In traditional product development programs, decisions made during the Concept Exploration (CE) and Product Design and Risk Reduction (PDRR) phases often locked-in 65% to 75% of the systems life-cycle cost and were difficult or extremely expensive to change later. In addition, changes were rigorously controlled by the government Program Office. The effect of this was to ensure that production programs were largely driven by very early decisions made with virtually no manufacturing input.

In today's acquisition environment the contractor has primary control of the detail design and the manufacturing processes. Contractors are responsible for managing their processes, their metrics, and their continuous improvement efforts. In this environment, when an improvement opportunity is identified, the contractor has authority to go directly to the process to make corrections, changes, and improvements without requesting government approval. With this authority comes an additional obligation: contractors must be responsible for any changes they may make. The Program Office requires a continuing *insight* into the changes made (as opposed to the historical *oversight* function). The contractor's configuration control of the product and the processes through process documentation, including an audit trail of all changes made, provides a vehicle for the effective functioning of this insight process.

9.2.3 Manufacturing Process Control and Continuous Improvement Guidance

In the Production phase the product IPT changes its focus from design and development to production, with manufacturing engineering evolving from a contributing function to a leadership function. This increasing focus on production should ensure effective implementation of manufacturing planning, effective control of manufacturing processes during production, and effective use of continuous improvement methods. The production contract should provide a vehicle for Program Office insight into program management and program status including the contractor's configuration control of Class II product and process changes.

Manufacturing planning should consider the production flow, the tooling, the ST/STE used to produce the product, operator skill requirements, and quality verification techniques to determine how various processes should be controlled and improvements identified and implemented. Manufacturing planning should be based on the documentation provided in EMD, and on the Program Office insight strategy to be implemented on the production contract. The contract should provide incentives for identifying and making any additional performance or affordability improvements in the design or in processes and production methods. Another consideration in implementing improvements in processes is the effect such improvements have on Key Characteristics. Continuous maintenance of the list of key characteristics should be performed as an ongoing part of the improvement process.

9.2.4 Manufacturing Process Control and Continuous Improvement Lessons Learned

The value of understanding, measuring, controlling and improving process performance has been demonstrated by numerous companies in both the commercial and defense sectors. A number of major acquisition programs which were under pressure to offset inflation penalties and the cost growth resulting from increased performance requirements have successfully employed formal process improvement measures, often coupled with special incentives or recognition. The strong emphasis placed by defect prevention techniques on understanding the process capabilities and generating positive process improvements toward six-sigma performance has demonstrated that cost growth can be contained. The linkage of process capabilities to continuous improvement using SPC tools, Variability Reduction techniques, and corrective action efforts has improved cost and schedule performance on programs and major subsystems.

9.2.5 Manufacturing Process Control and Continuous Improvement Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Content

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

9.3 Key Suppliers

9.3.1 Introduction

Please refer to section 8.5.1.

9.3.2 Key Suppliers Rationale

Please refer to section 8.5.2.

9.3.3 Key Suppliers Guidance

Please refer to section 8.5.3.

9.3.4 Key Suppliers Lessons Learned

Please refer to section 8.5.4

9.3.5 Key Suppliers Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Content

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this practice

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

9.4 Variability Reduction

9.4.1 Introduction

For a detailed discussion of VR, please refer to section 7.6.

Production phase variability reduction (VR) efforts are primarily concerned with maintaining an environment of continuous improvement in product and process quality. During the production phase, process capability and product quality should continue to improve even after the baseline program requirements have been achieved. The team should strive to achieve process stability for all critical processes and to continually improve process capabilities.

Production phase VR efforts fall into four areas: (1) data collection during production operations to monitor process performance and initiate preventive actions; (2) the implementation of process improvements during build activities; (3) assessment of feedback received from field users and support personnel, and field reliability data; and (4) implementation of design enhancements to improve performance, producibility, and affordability.

9.4.2 Variability Reduction Rationale

For a detailed discussion, please refer to section 7.6.2.

9.4.3 Variability Reduction Guidance

For a detailed discussion, please refer to section 7.6.3.

9.4.4 Variability Reduction Lessons Learned

For a detailed discussion, please refer to section 7.6.4.

9.4.5 Variability Reduction Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this practice.

Instructions To Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

9.5 Factory Efficiency

9.5.1 Introduction

Historically, discussions of factory efficiency concentrated on the measurement of worker performance and traditional manufacturing process improvement, which improved efficiency by eliminating waste. Although these activities are still important, in the austere acquisition environment which characterizes today's weapon system development programs, achieving factory efficiency implies the continuous application in the production facility of all appropriate lean manufacturing practices and high performance manufacturing systems. It also implies a dedication to continuous improvement practices and principals during production. The ultimate objective of factory efficiency is achieving an effective balance between product performance and affordability. There are several recently developed tools to help us achieve that balanced goal.

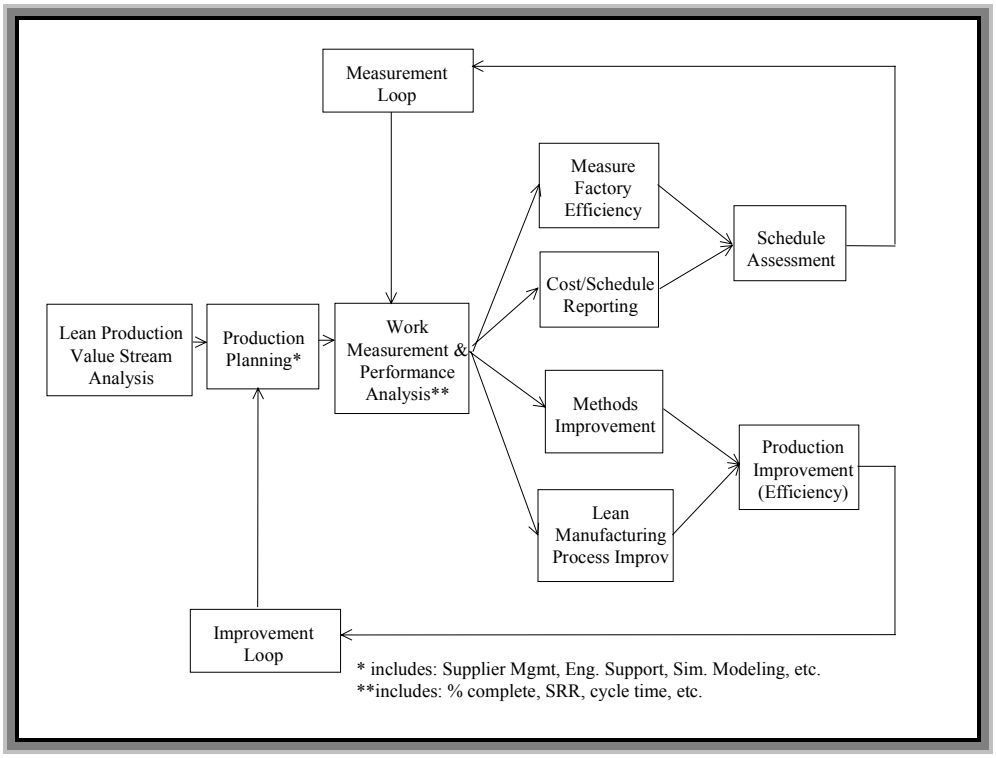


Figure 9-1. How the Factory Efficiency Practice Area Integrates with Other Practices

Factory efficiency issues extend far beyond the confines of the factory floor. Focusing effectively on risk management and on total program costs requires evaluators and decision-makers to consider applicable value stream effectors such as industrial base issues, production capacity issues, and new approaches to make vs. buy decisions. In this environment, the government's Program Office and its manufacturing engineering representative may find themselves at the center of a conflict between short term and long-term solutions. To achieve an optimal balance, the manufacturing representative must adopt a long term cost planning horizon and recognize the role factory efficiency plays in the bottom line cost of the system and recommend the best solutions to program management.

9.5.2 Factory Efficiency Rationale

In the activities leading up to, and during, the production phase of today's acquisition programs, the role of the government Program Office's manufacturing engineering representative should include a new and determined focus on achieving affordability and best value. This requires a much broader perspective than the conventional attention to the contractor's technologies, facilities, and processes. It may include consideration of such issues as:

- Overhead absorption – as a result of dwindling defense and related commercial business, many programs see program indirect factory cost rise as the number of programs sharing the contractor’s overhead pool shrinks

- Critical mass - need for a certain minimum production rate to efficiently produce a system; a

common issue when program funds are cut and annual production quantities are reduced

- Industrial base sustainment – another consequence of the reduction in defense related business; Concern over loss of competition and, in extreme cases, the ability to acquire necessary components

- Capacity constraints –contractor's have a limited flexibility to ramp up production in response to a spike in demand, and our relative position and leverage as purchasers of that flexibility has decreased as we become a smaller percentage of total business

- Measurement –Activity Based Costing and Cost-As-An-Independent-Variable (CAIV) allow application of new approaches to manufacturing accounting, tying factory efficiency to other program objectives and performance measures.

The Program Office's manufacturing engineering representative should participate with the contractor in the use of such tools as cost modeling and discrete event simulations in order to analyze the risks and benefits associated with these overarching production issues.

9.5.3 Factory Efficiency Guidance

The use of Integrated Product and Process Development (IPPD) has expanded the role of the Program Office's manufacturing engineering representative, allowing a greater opportunity to positively affect the performance and affordability of the program. This role should encompass championing improvements in the government's processes, schedules, and requirements as well as internal improvements in the contractor's manufacturing methods and processes. Creation of innovative financial incentives may be required to encourage all team members to embrace the long-term benefit of process improvement methodologies like Lean over short-term lower cost solutions.

The following ideas and tools may be considered for implementation if their cost is outweighed by their benefits:

- Continuous process flow – production process part movement based on a principle of Lean Manufacturing that breaks the production line into a sequence of short duration, perfectly synchronized tasks which minimize delay, wasted effort, and in-process inventory.

- Discrete Simulation – a computer simulation based on analysis of the discrete activities, or events, associated with a production process. The simulation allows for much more accurate estimation of schedule and cost considerations than is otherwise possible.

- Single Process Initiatives (SPIs) – an initiative encouraging and facilitating the establishment of common support processes across military procurements, eliminating the need for redundant systems at contractor's facilities.

- Just-in-time manufacturing and inventory systems – a resource allocation and part supply strategy (requiring a predictable well timed production process) where the delivery of production parts, tools and other resources occur exactly when (or very shortly before) they are needed.

- *Kanban* card inventory pull systems – a process control and synchronization tool designed to facilitate small lot size and ultimately single piece flow by limiting in-process inventory, bringing the next work piece from the previous work station only when the station is ready to receive it (usually indicated by receipt of a Kanban card).

- Empowered employee teams – an organizational decision-making strategy allocating authority and responsibility to appropriately trained employee teams (usually cross-functional membership) for short intense improvement efforts or long term project management.

- Business unit production cells – method for laying out production organizations in process-based cells as opposed to traditional functional layouts based on common machine type, so that each business unit is a complete production organization that can be flow analyzed and optimized.

- Process-based or activity-based cost management – method of cost management based on assigning cost to each activity performed by the resources (including many that were traditionally considered untouchable and fixed), improving management's understanding of a process's cost drivers and their ability to control total cost.

The production contract should provide Program Office insight into the contractor's manufacturing management processes through delivery of relevant plans and reports, or through access to contractor management information systems as part of normal team interaction. The IPT cognizant of the development process continues through the production phase with changes in membership based on new tasks, and with the IPT manufacturing engineering function moving from a participatory role to a leadership role. The contract should be tailored to continue the Program Office's role in monitoring best value evaluations and make vs. buy decisions, and encourage the use of cost modeling and capacity analyses.

The role of the government's manufacturing engineering function is to represent the customer's interests in effective risk identification and, if possible, mitigation of cost, schedule, and quality risks--and to maintain a sensitivity to larger considerations such as industrial base issues and capacity constraints. This role includes the analysis of economic data to support contractor decisions aimed at optimizing the acquisition process over a total product life cycle rather than for the immediate contract alone.

9.5.4 Factory Efficiency Lessons Learned

The Lean Aircraft Initiative and other initiatives promoting factory efficiency grew out of recognition of the impacts of global competition on the defense acquisition process. With a de-emphasis of the requirement for U.S. sources to supply all contract requirements, and with the rise of high performance products globally, the need to implement lean practices has become a survival issue. Defense contractors at all levels of the supply chain are embracing lean principles and building on lessons learned in the U.S. auto industry and other commercial competition sectors.

The C-17 program had substantial success overcoming short-term profit motive barriers to achieve long-term improvements using a Performance Based Payment approach combined with Multi-year contracting. Performance Based Payments tie partial payments under the contract (traditionally Progress

Payments) to measurable progress toward delivery of contracted systems (completion of subassemblies, for example).

With the Acquisition Reform emphasis on eliminating all but the most essential data requirements, Manufacturing and Quality Assurance representatives increasingly find themselves in a position where they are required to aggressively defend the requirement for factory efficiency data. Winning the argument for receiving this data is critical to program success on everything but a straightforward COTS procurement, or other fixed price contract with little or no development effort. We have seen the negative consequences of an inadequate understanding of factory capabilities, and program management must be made to understand that eliminating this data requirement means blinding themselves to a contractor's real ability to perform to a contract delivery schedule. Lack of data degrades a program office's ability to respond to "What-If" scenarios, or to independently assess a contractor's recovery schedule.

Cost Schedule Control Systems Criteria (CSCSC) data is an important part of most program management metrics and it is often used to draw conclusions about program performance as measured in cost and schedule status. It is important that Manufacturing and Quality Assurance personnel have a basic understanding of this data, and can interpret the reports generated by their contractor to meet CSCSC requirements. This information combined with access to and understanding of factory efficiency data can give a complete picture, not only of where the program has been, but where it is going. If a conclusion reached in CSCSC appears to be contradicted by other factory data the differences need to be reconciled.

9.5.5 Factory Efficiency Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Content

Contract Data Requirements List (CDRL) Guidance

CDRLs will vary depending on the type of contract imposed, the degree of new development effort, and the phase of the acquisition lifecycle. Minimizing the number of actual CDRLs is highly desirable, and it may be possible to eliminate delivery of paper entirely through agreements on shared access to contractor's databases (a common practice within IPTs).

- Summary Production Schedule
- Labor Performance Data (actual hours vs. work measurement standards)
- Intermediate Detailed Departmental Schedule and Performance Charts
- Line of Balance Charts
- Supplier Factory Metrics (when available)

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

9.6 Product Improvement

9.6.1 Introduction

Product improvement is a practice used throughout the defense industry that has gained new emphasis in the era of reduced budgets and acquisition reform. Product improvements are changes made in the production phase to address new performance requirements and/or to take advantage of new technologies or subsystems that enhance performance or lower cost.

Performance based specifications have changed the processes for product improvement, giving the contractor greater flexibility to make changes that improve or do not adversely affect performance (provided that the design and performance implications are validated and verified as part of the change process). Product improvements that affect form, fit or function and therefore impact interchangeability, spares, or other areas call for program-level approvals prior to proceeding.

The use of block contract changes and single process initiatives (SPIs) provides for controlled, efficient, and cost effective introduction of changes. Significant administrative costs are avoided when a product design improvement is implemented simultaneously on multiple contracts via the block contract change process. Further, if manufacturing implementation of the product improvement requires a change to a process used on programs throughout a contractor's business base, then a related SPI generates greater cost avoidance by precluding the need for multiple processes to satisfy the same product requirement.

Configuration "Block Upgrades," not to be confused with the Block Contract Changes described above, is a technique that is used on major weapon systems to introduce multiple product improvement changes on a periodic basis. On the C-17 program this is currently an annual configuration update; however, there is discussion on lengthening the block process to once every two years. On the F-16 and several other programs, block changes occur every few years. Under the Block Change concept, all products within a given block have essentially the same configuration. This results in reduced sustainment costs by minimizing unique spare, tech order, and support equipment and training requirements. Stable configurations within a block of aircraft or products improve manufacturing efficiency and quality. However, diligent manufacturing development and transition planning is required to minimize production line disruptions when introducing a new Block with significant configuration changes.

9.6.2 Product Improvement Rationale

Product improvement during the production phase of a program is the result of the need to meet new performance requirements, correct design deficiencies, improve product yield for cost, schedule and quality reasons, or to take advantage of new product or process technologies. With performance-based specifications, contractors have more authority to incorporate changes. The manufacturing engineer's role is to assess the projected impact of such changes on the manufacturing process and plan the incorporation of the change in the factory.

9.6.3 Product Improvement Guidance

Government Program Office manufacturing engineers need to be involved from the start of the Product

Improvement effort. They need insight into the contractor's product improvement planning to ensure the contractor includes manufacturing planning and risk reduction efforts. Design review entrance criteria must ensure manufacturing and sustainment impacts have been identified and risks are either acceptable or have acceptable risk mitigation actions approved by program leadership. For product improvements initiated to achieve production cost savings, the manufacturing engineer must assess impacts to sustainment including spares inventories and tech orders. The manufacturing engineer must have insight into these impacts to ensure the contractor includes them in the cost benefit analysis during the project approval process. Insight into the production cost model and the manufacturing simulation models will help identify and mitigate these risks early in the improvement process.

9.6.4 Product Improvement Lessons Learned

Contractors have often introduced product changes to improve fit and function based on quality data gained through the process of maintaining a continuous learning curve reduction over time. The customer often adds new requirements based on new threats or lessons learned in the deployment of the product. Historically, these changes result in increased costs. Without a block change process, changes are often incorporated in a manner that can add to unit cost as well as to life cycle costs for support. Programs have often experienced obsolete spares inventories and expensive changes to support equipment due to loosely managed product improvements. Cost growth is often associated with added performance requirements.

9.6.5 Product Improvement Recommended RFP/Proposal Content

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Content

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors Guidance (Section L)

Evaluation Criteria Guidance (Section M)

9.7 Manufacturing Capability Assessment & Risk Management

9.7.1 Introduction

In the production phases of today's acquisition programs, the role of the government Program Office's manufacturing professional may include selecting the best value source and providing manufacturing risk assessment to the program manager. Manufacturing personnel reduce program risk through their activities at source selections including assessment of manufacturing capabilities against the acquisition requirements. After the source is selected the Manufacturing component of program risks must be understood, and properly communicated to the government program manager. The manufacturing manager must help propose and evaluate best value solutions to the identified risks

9.7.2 Manufacturing Capability Rationale

ASC/CC Letter dated 12 January 1999 requires that, "Every competitive RFP issued for an action executed at ASC shall follow the ASC pre-award process no matter who owns the program, i.e. PEO, ASC DAC or other center DAC. All single managers and 2-letter equivalents using ASC resources shall implement this pre-award process within the applicable parts of their organizations." The referenced process includes risk mitigation steps, where manufacturing capability determination is often the basis for selecting best value sources.

9.7.3 Manufacturing Capability Guidance

The manufacturing capability evaluation is to provide Program Office insight into the contractor's manufacturing technical and management processes. The IPT that has been established to execute the procurement conducts the source selection and the production phase with significant support from the manufacturing function. The role of the government's manufacturing function is to provide effective risk mitigation options for cost, schedule, and quality--and to maintain a sensitivity to overarching considerations such as industrial base issues and capacity constraints. Typical (not inclusive) Manufacturing Capability considerations in the Production phase are:

- Industrial Base
- Design Stability/Producibility
- Quality Management Systems
- Software capabilities
- Lead-times
- Technical Data Package
- Surge/Mobilization Capacity
- Manufacturing Technologies
- Work Instructions
- Material
- Resources
- Tooling (capability to design and produce)
- Process/Tooling Proofing

9.7.4 Manufacturing Capability Lessons Learned

The T-38 Propulsion Modernization Program, even though a build-to-print effort, still had numerous manufacturing capability risks identified by the competing small businesses. The Program Manager, in consultation with the Director of Manufacturing, assigned high priority to manufacturing capability and included a substantial manufacturing evaluation in the source selection.

9.7.5 Manufacturing Capability Recommended RFP/Proposal Content for Non-Developmental Systems

Government Statement of Objectives (SOO)

Contractor Statement of Work (SOW)

Integrated Master Plan (IMP) Content

N/A

Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

Instructions to Offerors (ITO) Guidance (Section L)

Evaluation Criteria Guidance (Section M)

Manufacturing Development Guide

Appendix I: MDG ACRONYMS

ACA	Associate Contractor Agreement
ANOVA	Analysis of variance
ANSI	American National Standards Institute
AUPP	Average Unit Production Price
CAD	Computer Aided Design
CAIV	Cost as an Independent Variable
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CE	Concept Exploration
CFP	Contractor Furnished Property
CI	Complex Item, as in a design specification
CO	Contracting Officer
CONUS	Continental United States
COTS	Commercial Off-the-Shelf
CPARS	Contractor Performance Analysis Review System
Cpk	Capability Index
CRAD	Contractor Research and Development
DAL	Data Accession List
DFx	Design for "x"
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DoDR	Department of Defense Regulation
DOE	Design of Experiments
DRFP	Draft Request for Proposal
DTC	Design to Cost
DUE	Data Update Events
EA	Environmental Assessment
EDI	Electronic data Interchange
EMD	Engineering and Manufacturing Development
EPA	Environmental Protection Agency
FMEA	Failure Mode & Effects Analysis
FTA	Fault Tree Analysis
GFE	Government Furnished Equipment
GFP	Government Furnished Property
ICD	Interface Control Document
IMP	Integrated Master Plan
IPPD	Integrated Product and Process Development
IPT	Integrated Product Teams
IRAD	Internal Research and Development
JACG	Joint Aeronautical Commanders Group
LAI	Lean Aircraft Initiative
LCC	Life Cycle Cost
LCCM	Life Cycle Cost Model
LRIP	Low Rate Initial Production
LRU	Line Replaceable Unit
MCA	Manufacturing Capability Assessment
MCRA	Manufacturing Capability Requirements Analysis
Mfg.	Manufacturing

MDG	Manufacturing Development Guide
MM/PCR	Manufacturing Management/Production Capability Review
MRP	Materials Requirement Planning
MRP II	Manufacturing Resource Planning
NDI	Non-developmental item(s)
NDI	Non-destructive Inspection
NGS-IPT	Non-Government Standards - Integrated Product Team
OSHA	Occupational Safety and Health Agency
PAC	Product Acceptance Criteria
PBBD	Performance Based Business Description
PBBE	Performance Based Business Environment(s)
PCM	Production Cost Model
PCR	Production Cost Requirement
PDR	Preliminary Design Review
PDRR	Program Definition and Risk Reduction
PMR	Program Management Review
Pre-EMD	Pre-Engineering and Manufacturing Development
QFD	Quality Function Deployment
RAA	Required Assets Availability
RFP	Request for Proposal
ROM	Rough Order of Magnitude
SE	Support Equipment
SEMS	Systems Engineering Master Schedule
SOO	Statement of Objectives
SOW	Statement of Work
SPC	Statistical Process Control
SPO	System Program Office
SPI	Single Process Initiatives
SRA	Schedule Risk Assessment
SRD	System Requirements Document
SRU	Shop Replaceable Unit
SSAC	Source Selection Advisory Council
SSEB	Source Selection Evaluation Board
ST/STE	Special Tooling/Special Test Equipment
SVR	System Verification Review
T1	first unit
TBD	To Be Determined
TDP	Technical Data Package
TIM	Technical Interchange Meeting
TQM	Total Quality Management
VM	Virtual Manufacturing

Manufacturing Development Guide

Appendix II: CONSOLIDATED LIST OF RFP INPUTS

System Specification Requirement

Engineering for Affordability

Production Cost. The [program name] average unit production price (AUPP) shall not exceed $_____ in [constant FY __ dollars] for [total volume or target volume and range] production units at a maximum production rate of [average rate/specific planned rate/target rate and range] per month. (Identify and define cost elements included and/or explicitly excluded). Cost allocations for Complex Items (CIs) shall be identified in the CI Development Specifications. [The average unit production cost goal for the system is $_____ in [constant FY __ dollars] for the same volume and rate(s)]

System Specification Verification

Production Cost. The [program name] AUPP requirement shall be verified by analysis using a joint government/contractor PCM and recognition of the current cost risk of the estimate.

Government Statement of Objectives

Quality Systems

- The government's objective is that the contractor implement an overarching quality system that ensures effective execution, integration, and administration of the design, manufacturing, and deployment processes and systems needed to manage risk, ensure achievement of all performance requirements, and prevent the generation of defective product.
- The system should also include a means for measuring the effectiveness of and ensuring the continuous improvement of systems and processes.

Pre-EMD Phase

Manufacturing Development. The government's objective is that the contractor implement those processes and systems that consider manufacturing, quality, and design functions in achieving a balanced design solution, which meets cost, schedule, and performance requirements with acceptable risk. The following may be considered as appropriate practices for implementation: identification of key characteristics and processes; variability reduction on product, process, and infrastructure; electronic simulations of the manufacturing environment; production cost modeling and Cost As an Independent Variable (CAIV); the use of IPTs to accomplish manufacturing risk management; and establishing active, collaborative relationships with key suppliers.

EMD Phase

Manufacturing Development. The government's objective is that the contractor implement those processes and systems that consider manufacturing, quality, and design functions in achieving a balanced product design description which meet cost, schedule, and performance requirements with acceptable risk. Appropriate practices for implementation may include identification of key characteristics and processes; variability reduction on product, process, and infrastructure; electronic simulations of the manufacturing environment; cost modeling and Cost As an Independent Variable (CAIV); cost/performance trade studies; use of commercial parts and specifications; use of IPTs; and key supplier relationships.

Production Phase

Production Quality and Manufacturing Efficiency. The government's objective is that the contractor implements those processes and systems to assure program affordability through product quality and manufacturing efficiency. The following elements may be considered as appropriate practices for implementation: product improvement initiatives; variability reduction on product and process; manufacturing process control and continuous improvement; use of commercial parts and specifications; use of IPTs; and key supplier relationships.

Contractor Statement of Work (CSOW)

All offerors are encouraged to address the topics below in their submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

Manufacturing Engineering's role in IPPD

- Formal processes and best practices to be followed by the contractor's integrated product teams.
- Means used to involve the government customer, the required internal disciplines (including manufacturing engineering), and key subcontractors in a collaborative design process.
- Identification of functional representation on the IPT at the organization chart level.
- Roles and responsibilities, reporting requirements, and program metrics to be followed by the IPTs.

Engineering for Affordability and Producibility

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Incorporation of cost in design/performance trade studies
- Flow down of cost targets to IPTs and key suppliers
- Offeror's formal cost risk management process

- Availability of "Engineering for Affordability" tools and training to suppliers
- The planned implementation of formal cost avoidance initiatives, programs, tools, and techniques

Quality Systems

- The contractor's SOW should address the tools and techniques that will be implemented and deployed within an overarching quality management system to prevent the production of defective products.
- The contractor's SOW should specify the means that will be used for measuring the effectiveness of all company processes that could affect quality of the product and for ensuring the continuous improvement of systems and processes.

Pre-EMD Phase CSOW Roll-up

Production Cost Modeling

- Ground rules and assumptions of the PCM.
- Configuration control of the PCM.
- Organization(s) responsible for keeping the PCM updated.

Manufacturing Capability Assessment

- How IPPD procedures used in the CE and PDRR phases will apply to process and production capabilities.
- Risk mitigation strategies for material and process issues.
- Risk mitigation that involves the building of virtual or physical prototypes of components.
- Concurrent development of ST/STE and SE as a schedule risk reduction procedure.
- Production capability or capacity issues, industrial base sustainment plans, and foreign-sourced materials.
- IRAD and internally funded activities that apply to the reduction of risk for the program, including a brief description of the technology, expected results, and schedule.
- The metrics used for evaluation of producibility and related cost impacts in the design trade studies, including those of key suppliers.

Key Suppliers

- Flow-down of the key characteristics and processes practice (see Chapter 7, Section 7.5, "Key Characteristics and Processes") to suppliers.
- Flow-down of key design features and key product characteristics (see Chapter 7, Section 7.5, "Key Characteristics and Processes") for which suppliers are responsible.
- Identification of key suppliers, including suppliers of GFP, and integration of supplier activities into the overall program plan.
- Early supplier participation in Integrated Product Teams (IPTs).
- Implementation of Associate Contractor Agreements (ACAs).
- Integration of key supplier events/activities into the IMP.
- Identification, analysis and management of supplier risk.
- Integration of the supplier risk management plan into the program risk management plan.

Key Characteristics

- Processes for identifying key product characteristics that most influence product performance, reliability, affordability, quality, and cost as appropriate to the level of design maturity.
- Documentation processes for identifying key characteristics in design and process drawings, specifications, and manufacturing instructions.
- Flowdown of key product characteristics and key process requirements to applicable suppliers.

Variability Reduction

- Process for documenting process control plans and evaluation of process variability and capability
- Process for providing feedback to the product design engineers on process capabilities
- Documentation of key supplier VR implementation.

Virtual Manufacturing

- Preliminary manufacturing planning, virtual manufacturing, and virtual prototyping tools to synthetically demonstrate and validate program approaches.
- Planned approach to virtual manufacturing to provide early links between design and manufacturing, and to facilitate performance trades.

<u>EMD Phase Roll-up - CSOW</u>

Production Cost Modeling

- Development and maintenance of a PCM containing production cost ground rules, assumptions and data required to estimate production cost as defined in the System Specification.
- Configuration control of the model, as well as overall government and contractor roles and responsibilities for development and maintenance.
- Implementation of the PCM as an element in the systems engineering trade study process to assess production cost impacts and maintenance of an analysis of the current production cost estimate.
- Use of the production cost estimate analysis to assess the risk of achieving the System Specification cost requirement, and formulation and execution of appropriate risk abatement efforts.

Design Trade Studies

- A design trade study process that establishes the detailed designs of the overall weapon system and ST/STE/SE, to include selection of fabrication and assembly techniques and design parameters and tolerances that are consistent with process capabilities. This process also includes documentation of design trade study results and disposition of recommendations as the design matures.
- Identification of key product characteristics and related key production processes.
- Rationale for the functional requirements allocations and the resultant detailed designs at appropriate key events and IMP Milestones.
- Identification of design trades which fall outside program constraints of cost or schedule, but offer the potential of significant cost, schedule or performance improvements.

Manufacturing Capability Assessment

- How IPPD procedures will apply to process and production capabilities in EMD.
- Risk mitigation strategies for material and process issues.
- Concurrent development of ST/STE and SE as a schedule risk reduction procedure.
- Progress toward achieving a robust product design in order to reaffirm tooling philosophy.
- Capability or capacity issues, industrial base sustainment plans, and any foreign-sourced materials included.

- Metrics used for evaluation of producibility and other cost issues in the design trade studies, including those of key suppliers.

Key Suppliers

- Flowdown of key characteristics process and key product characteristics to responsible suppliers.
- Identification of key suppliers, including suppliers of GFP, and integration of supplier activities into the overall program plan.
- Early supplier participation in IPTs.
- Participation of GFP contractors in IPTs (via ACAs).
- Identification, analysis and management of supplier risk.
- Integration of supplier risk management planning into the overall program risk management plan.

Key Characteristics

- Identification of key product characteristics, as design matures, that influence design performance, affordability, quality, and cost.
- Processes that balance product design requirements with manufacturing process capabilities.
- Processes for documentation of key characteristics, processes, and parameters on drawings and in appropriate process specifications.
- Flowdown of product key characteristics and processes to suppliers with design responsibility.

Variability Reduction

- Determination and documentation of design margins, process capability requirements, and process control requirements for key processes and process parameters.
- Matching of product design requirements to manufacturing capabilities during the product definition process.
- Development and demonstration of methods for evaluation of process stability and capability, and for assessment of the potential for quality improvements to the product design and production processes.
- Key supplier development, implementation, and maintenance of a VR methodology encompassing all key characteristics for which they are responsible.

Long Lead

- Long lead items incorporated in the preliminary manufacturing plan and the IMP.
- ST/STE/SE (required to support the test article build plan, line proofing, process verification, and LRIP) incorporated in preliminary manufacturing plan.

P&P Validation

- The appropriateness of the effort to the program considering the availability of advanced production capability demonstration resources.
- The inclusion of teammates and major suppliers in the production and process validation effort.
- The use of production and process validation to verify the build-to documentation and demonstrate the capability of the ST/STE and the processes, plans, and facilities for initial production.
- Distinctions between prototype facility processes and production facility processes.
- The scalability of any prototype facilities employed.

Production Phase Roll-up - CSOW

Process Control

- The company's process control procedures for manufacturing processes, related documentation, including configuration control of processes and ST/STE, production process flow, and production processes and methods.
- The communication of changes with respect to any of these items and the issue of insight for government representatives.
- Processes for identifying further opportunities for improved performance and affordability.

Key Suppliers

- Identification of key suppliers including key suppliers of GFP and integration of supplier activities into the overall program plan.
- Key supplier participation in IPTs.
- Integration of key supplier events/activities into the IMP.
- Identification, analysis, and management of supplier risk.
- Integration of the supplier risk management plan into the overall program risk management plan.

Variability Reduction

- Plans for data collection and analysis, evaluation and monitoring of process stability and

capability, and assessment of potential benefits of process improvements.

- Implementation of VR methods by key suppliers.

Factory Efficiency

- Factory efficiency initiatives which will be used to achieve the proposed Average Unit Production Price (AUPP).
- Continuous production improvement practices to be used in the production phases.

Product Improvement

- IPT control of the configuration change control process.
- Manufacturing Engineering insight into Production Cost Model impact and the simulation model.
- ST/STE/SE considerations as addressed in the change process.

Manufacturing Capability

- The contractor shall establish and maintain the manufacturing capability to acquire, produce, assemble, and deliver the contracted items, using materials and processes identified in the government-provided drawing/specification package.
- The contractor shall ensure quality and manufacturing efficiency through variability reduction and continuous improvement of processes that produce components and final assemblies meeting requirements.
- The contractor shall accomplish day-to-day production planning, management and control of this program. The contractor shall effectively manage all tasks, facilities, and personnel required to produce these components at the prime and subcontractor facilities.
- The contractor shall be responsible for the effective management of all subcontracts that provide development and production components for installation into the final inlet assembly. The contractor shall be responsible for prompt program office notification of impending subcontracted item delays.

Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval to Begin Program)

Manufacturing Engineering's Role in IPPD

- Manufacturing participation in product development is evident through the fulfillment of MDG-related exit criteria, such as leadership in producibility studies, evidence of objective process knowledge, and analysis of process cost implications in affordability risk studies.
- PCM demonstrates that the cost objective is achievable.
- Manufacturing process design considered in product design engineering practices.
- IPPD processes employed to define initial production concepts.
- Customer/user and supplier participation documented in IPT and requirements definition activities.
- Appropriate consideration of multi-functional IPT inputs reflected in documentation of trade-off decisions.

Engineering for Affordability and Producibility

- Preliminary production concepts identified. Preliminary cost partitioning of major assemblies accomplished.

Pre-EMD IMP Roll-up - Milestone I

Production Cost Modeling

- Preliminary production cost estimate documented, including back-up calculations, ground rules, assumptions, and rationale.

Manufacturing Capability Assessment

- Materials lacking mature processes identified for manufacturing risk management purposes.
- IRAD and other programs established to reduce risk.
- Manufacturing capability database architecture defined.
- Manufacturing capacity issues identified.
- Industrial base sustainment issues identified.

Key Suppliers

- Key technology teams and strategic business alliances initiated.
- Key supplier risk assessment performed and manufacturing risk mitigation planning initiated.
- Flow-down of MDG practices to key suppliers initiated.
- Key supplier performance requirements flow-down and agreement established.

Key Characteristics

- Key Characteristics and Processes plan established.

Variability Reduction

- Preliminary VR planning accomplished

Virtual Manufacturing

- Production concepts demonstrated through simulation.
- Cost objectives and affordability initiatives confirmed through simulation.

Milestone II (Approval to Enter EMD)

Manufacturing Engineering's Role in IPPD

- Manufacturing participation in design is evident through the fulfillment of MDG-related exit criteria, such as leadership in producibility studies.
- Evidence exists that process considerations have influenced the product design.
- PCM demonstrates that cost objective is achievable, and associated risk reduction tasks are identified in the IMP.
- Results of producibility studies are accounted for in the product design approach.
- Customer/user and supplier members actively participated in IPT.
- Process maturation plans have been employed.

Engineering for Affordability and Producibility

- Initial cost estimates support program goals and cost risks and drivers are identified
- Results of cost vs. performance trade studies obtained
- Cost requirement flowdown refined

- Cost management/reduction systems developed and implemented

Pre_EMD Phase Roll-up - Milestone II

Production Cost Modeling

- Preliminary production cost model (PCM) acceptable to the government.
- Updated production cost estimates documented.

Manufacturing Capability Assessment

With the Manufacturing Capability Assessment completed and risk mitigation initiatives planned, key areas addressed include:

- New and/or environmentally questionable materials and processes included in program risk management planning.
- Contributions of IRAD and other independently funded programs factored into program schedule.
- Manufacturing capability database includes all technologies applicable to identified Key Characteristics.
- All risk reduction activities factored into program schedule.
- Industrial facilities and manpower requirements planning included in IMP.
- Industrial base sustainment issues included in IMP.
- Test requirements and test articles identified in IMP.

Key Suppliers

- Key process characteristics and key product characteristics flow-down initiated.
- Key supplier Manufacturing Capability Assessment (MCA) performed and results presented.
- Preliminary tolerance flow-down/error budget established.
- Preliminary EMD manufacturing plans for key suppliers established.
- Preliminary electronic manufacturing simulations by key suppliers identified.
- Associate Contractor Agreements finalized with key GFP suppliers.
- Risk assessment and events/activities for key suppliers included in Integrated Master Plan.

Key Characteristics

- Preliminary key product characteristics identified.
- Preliminary key processes identified.
- Supplier flowdown of product key characteristics and key processes established.

Variability Reduction

- EMD phase VR planning completed.
- A process is in place for matching key product characteristic design requirements to process capabilities.
- Key supplier VR flowdown and training initiated.

Virtual Manufacturing

- Simulations demonstrate ability to meet producibility and affordability goals.
- Manufacturing risk areas included in simulations.
- Baseline established for EMD production activities.

Interim Event (corresponding to historical Preliminary Design Review)

Manufacturing Engineering's Role in IPPD

- Manufacturability of the design is evident through fulfillment of the MDG-related exit criteria, such as process maturity plans.
- Validation of process capability index is being confirmed for key processes using representative materials
- Designed experiments have been used to define a first approximation to optimum settings for process attributes.

<u>EMD Phase Roll-up - IMP - PDR</u>

Production Cost Modeling

- Initial Contractor PCM developed and under formal configuration control.
- Rationale provided to correlate initial cost estimates and cost risk mitigation effort to achieve an acceptable production cost estimate.

Design Trade Studies

- Functional allocation of System Specification requirements, including the Production Cost Requirement and overall estimate of Life Cycle Cost.
- Design trade process implemented for evaluating alternative materials and production processes and identifying key product characteristics and related key production processes, including the results of key supplier efforts.
- Contractor's planned key events and their exit criteria, as reflected in the IMP.

Manufacturing Capability Assessment

- Manufacturing Capability Assessment updated.
- Preliminary test article build plan complete.
- Rationale provided to demonstrate adequacy of risk abatement plans.
- Risk abatement milestones included in IMP.
- Process capability database includes all key processes.
- Plan identified to match product requirements and process capabilities.
- Supplier capacity risks identified and included in risk management planning.
- Plan for COTS/industrial base risk complete.
- Preliminary LRIP plan complete.

Key Suppliers

- Key suppliers identified and selected and subcontracts negotiated.
- Key supplier concurrence with requirements allocation and flowdown accomplished.
- Key supplier identification of key product characteristics.
- Associate Contractor Agreements finalized with GFP suppliers.
- Supplier Manufacturing Capability Assessment (MCA) (See Chapter 8, Section 8.5 "Manufacturing Capability Assessment and Risk Management") performed and results presented for suppliers not previously evaluated.

Key Characteristics

- Identification of preliminary key product characteristics complete.

- Identification of preliminary key processes complete.
- Flow down of key process requirements complete.
- Drawing system/standards and drawing release criteria defined prior to start of detailed design.

Long Lead

- Long lead items identified.
- ST/STE/SE requirements identified.

P&P Validation

- Key product components and processes evaluated from a validation standpoint.
- New processes verified and validated incrementally.
- Additional tests required for verification and validation identified.

Interim Event (corresponding to historical Critical Design Review)

Manufacturing Engineering's Role in IPPD

- Manufacturing Engineer and supplier participation in IPTs and design trades.
- PCM demonstrates that cost objective is met.
- Key characteristics and key processes are matched for prime and sub contractors.
- Process capabilities are adequate for product requirements for prime and subcontractors.
- Simulations have validated the assembly process.
- Supplier participation in IPTs assures a robust process design.

Engineering for Affordability and Producibility

- Production cost models reflect the impact of the design solution on manufacturing costs
- Production cost estimates demonstrate cost objective is achievable
- Cost mitigation actions are being completed
- Producibility studies have been completed and recommendations are incorporated in the product design

EMD Phase Roll-up - IMP - CDR

Production Cost Modeling

- Rationale provided to correlate cost estimates based on detailed design and cost risk abatement effort to achieve an acceptable production cost estimate.

Design Trade Studies

- Detailed design (product/ST/STE/SE) including production cost assessments and key product characteristic's design limit sensitivity to off nominal production; details to include the results of key suppliers' efforts.
- Selection of production processes, including comparison of required process capabilities to documented capabilities.
- Contractor's planned key events and their exit criteria included in IMP.

Manufacturing Capability Assessment

- Manufacturing Capability Assessment updated.
- Test article build plan complete.
- Rationale provided to demonstrate adequacy of risk abatement plans.
- Process capability demonstration plan complete and included in IMP.
- LRIP plan complete.

Key Suppliers

- Key supplier detailed designs complete.
- Key supplier identification of key process parameters complete.
- Key supplier preliminary process specifications complete.
- Key supplier risk assessment input provided to prime contractor.
- Key supplier events/activities included in IMP.

Key Characteristics

- Final key product characteristics determined.
- Final key production process parameters determined.
- Preliminary specifications for key processes developed.

Variability Reduction

- VR Program plan is in place

- Initial process control plans have been developed
- Process capability studies are being conducted with results fed back to product design
- VR metric developed

Long Lead

- LRIP Plan includes long lead item acquisition and ST/STE availability for LRIP.
- Risk management planning addresses long lead items and reduction initiatives.
- EMD funding sources support non-recurring needs.

P&P Validation

- All ST/STE scheduled for verification and validation before LRIP.
- IMP identifies all open tests.
- Risk management plan identifies all open risk items.

Interim Event (corresponding to historical System Verification Review)

Manufacturing Engineering's Role in IPPD

- Manufacturing Engineer leads LRIP IPT activity.
- PCM demonstrates low risk in achieving cost objective.
- Simulations verify and validate assembly processes prior to LRIP.
- Risk reduction tasks for manufacturing processes are completed successfully.

<u>EMD Phase Roll-up - IMP - SVR</u>

Production Cost Modeling

- Rationale provided to correlate final cost estimate based on development test results, test article build experience, (and, when applicable, Low Rate Initial Production [LRIP]) and any remaining cost risk abatement effort to be completed prior to production which results in an estimate which meets the System Specification PCR.

Design Trade Studies

- Final product/ST/STE/SE design based on results of test and evaluation, including the

results of key suppliers' efforts

- Identification of potential opportunities for improving cost, schedule and/or performance beyond baseline requirements.
- Contractor's planned key events and their exit criteria included in IMP.

Manufacturing Capability Assessment

- Rationale provided to demonstrate adequacy of production risk mitigation plans.
- Process capability verification complete

Key Suppliers

- Key supplier designs documented and baselined.
- Final specifications for supplier processes completed.
- Key supplier risk assessment completed.
- Key supplier events/activities included in IMP.

Key Characteristics

- Final specifications for all key processes developed.
- Preliminary Build-to documentation complete including identification of key characteristics.

Milestone III (Approval to Enter Production)

Engineering for Affordability and Producibility

- Production cost estimates demonstrate production cost requirements are achievable with acceptable risk

Key Characteristics

- Final Build-to documentation complete, including identification of key characteristics and control plans for key characteristics.

Variability Reduction

- Process capability data is being collected on processes affecting KCs and is available to the IPTs
- Process stability and capability have been determined for key processes. For those with insufficient data, estimates of stability and capability have been made.

- Process improvements have been initiated for processes with unacceptable variation
- Metrics are used to measure the progress of the VR program

Production Phase IMP Roll-ups

Process Control

- Continuous collection and periodic review of production and quality data to identify areas for improvement.
- Use of production data to identify improvement opportunities
- Tracking of process improvements and changes.
- Processes used in LRIP are documented for use in production, including control methods.
- Configuration control for design documentation provides visibility into changes.
- Manufacturing tooling and ST/STE/SE documentation are under change control.
- Processes and methods documentation are under change control.

Key Suppliers

- Key suppliers identification and selection, and subcontracts negotiation.
- Key supplier concurrence with requirements allocation and flowdown.
- Key supplier risk assessment and abatement planning and implementation.
- Verification/validation of key supplier process control and VR processes.

Factory Efficiency

- Program Office insight for make vs. buy procedures.
- Implementation initiatives focused on elimination of non-value-added activity and/or optimization of production cycle time (such as Lean Aerospace Initiative).
- Continuous improvement process documentation.
- Total acquisition costs in economic analysis.
- Use of cost models in economic decisions.
- Management of cost, schedule, and quality risk in the production environment.

Product Improvement

- Production phase support for timely delivery of the product.
- Block change planning in the IMS to assure that everyone understands and supports the schedule for incorporating changes.
- Changes which impact ST/STE/SE.
- In the PCM, product improvements are incorporated as block changes and non-recurring costs are identified.

Instructions to Offerors Guidance (Section L)

Section L should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

Manufacturing Engineering's Role in IPPD

- The IPPD processes which the offeror proposes to employ.
- The proposed approach to populating multi-functional teams and ensuring participation by suppliers and/or customers.
- A description of previous experience with IPPD processes (including performance metrics and demonstrated cost and schedule benefits).
- Plans to introduce and institutionalize the IPPD process in the offeror's organization (if the offeror has no previous IPPD experience).
- A description of the methodology used by the IPT for validating process cost and capability data to support trade decisions.

Engineering for Affordability and Producibility

- Processes for allocating cost requirements to lower level IPTs and suppliers
- Description of formal programs/tools/techniques to be used in engineering for affordability to maximize cost avoidance in manufacturing and sustainment
- Methods for including cost considerations in design trade studies
- Description of cost risk identification/mitigation processes
- Flowdown of engineering for affordability tools, techniques, and practices, along with related training, to appropriate suppliers.

Quality Systems

- How the quality system will ensure establishment of capable processes, adequate monitoring and control of critical processes and product variation, establishment of mechanisms for feedback of field product performance, implementation of an effective root cause analysis and corrective action system, and continuous process improvement.
- The offeror's quality systems should be described in the proposal to confirm that a formal, systematic approach is in place to assure product quality and prevent the generation of defective product.
- The test and evaluation program should reflect the incremental verification of objectives

throughout the design cycle.

- The offeror should provide for government insight into the quality program and should flow down this insight process to appropriate suppliers.
- The proposal should reflect the offeror's plans for using commercial or industrial standards in place of government specifications, and the strategy for implementing these standards with suppliers.
- The offeror should provide information on past performance of their quality systems and plans for improvement.
- The offeror should incorporate appropriate elements of the proposed quality system into the final contract through the Integrated Management Plan.

Pre-EMD Phase Roll-up - Section L

Production Cost Modeling

- Processes for development of the Production Cost Model.
- Processes for development of production cost estimates.
- Data pertaining to use and performance of PCM on previous programs.

Manufacturing Capability Assessments

- Identification of new and environmentally questionable materials and processes.
- Environmental-related manufacturing risk factors incorporated into risk management planning.
- Identification of related issues outside the scope of this program, including funding sources such as IRAD, CRAD, and related contracts.
- Industrial capacity and industrial base sustainment issues.
- IMP reflection of risk management activities.
- IMS reflection of cost and schedule risk management activities associated with the time phasing and stability of funding from other sources.

Key Suppliers

- Approach to identification and selection of key suppliers, including key supplies of GFP, along with criteria used to make the determination.

- Approach to integration of key supplier activities into the overall program plan, including descriptions of the tasks involved, and events, with exit criteria, to be tracked to assure that supplier activities support overall program performance.
- Performance specification, key process parameters, and key product characteristics flow-down.
- Processes for evaluation of key supplier performance, including key suppliers of GFP (after appropriate contractual mechanisms for relationships with key suppliers of GFP have been put in place).
- Past performance data relative to management of key supplier schedules and involvement of key suppliers in IPT activities
- Data pertinent to key supplier past performance in areas such as manufacturing capabilities, use of defect prevention techniques, customer satisfaction, and schedule adherence.
- Data to be collected and analyzed on the present program.
- Approach to integrating the risk management effort for key suppliers with the program risk management effort (including cost, schedule, and technical risks).

Key Characteristics

- Description of a process which identifies key product characteristics and ties them to key production processes
- Data pertinent to prime contractor and key supplier past performance in key product characteristics and key process identification. Results achieved from previous efforts, such as reduced number of KCs through redesign, cost reductions, etc.

Variability Reduction

- A description of the planned approach to variability reduction.
- Availability and planned utilization of defect prevention techniques and process control tools for controlling processes and assuring product quality.
- Data on prime contractor and key supplier past performance in variability reduction, process control, and product / process matching.

Virtual Manufacturing

- Virtual manufacturing, prototyping, and planning processes to be used in the pre-EMD program phase to ensure the effective early involvement of manufacturing engineering in the IPT design effort.
- Early involvement of virtual manufacturing tools to provide input to production planning and to production risk identification and management.

- Resources and experience needed to execute virtual manufacturing applications for the transition of the concept design into EMD and Production.

EMD Phase Roll-up - Section L

Production Cost Modeling

- Established processes and procedures for developing and validating a PCM.
- Documentation and maintenance practices for control of the PCM configuration.
- The contractor's preliminary model for evaluation, if available.
- Data pertinent to prime contractor and key supplier past performance in developing and maintaining realistic PCMs or similar models.

Design Trade Studies

- Basic trade study processes to be employed, including selection criteria for principal participants and integration of planned design trade studies and results into the IMP.
- Process for System Specification requirements allocation and flow down.
- Implementation of requirements for ST/STE/SE during the design process.
- Data pertinent to the prime contractor's and key suppliers' past performance in accomplishing design trade studies, with emphasis on such studies performed under the IPT concept, including metrics which identify performance with respect to cost, schedule and product performance.

Manufacturing Capability Assessment

- How the specific manufacturing risks will be addressed, including subcontractors, and the metrics to be used and how risks will be documented and reported.
- How the risk management effort will be integrated with the overall systems engineering and IPPD processes.
- Process capability database includes all key processes.
- Industrial base sustainment issues.
- Effective minimization of all hazardous materials.
- Inclusion of the environmental assessment task in the Integrated Master Plan.

Key Suppliers

- Approach to identification and selection of any new key suppliers, including key suppliers of GFP, along with criteria used to make the determination.
- Processes for evaluation of key supplier performance, including suppliers of GFP (after appropriate contractual mechanisms for relationships with key suppliers of GFP have been put in place).
- Processes for integration of key supplier activities into the overall program plan, including a description of the tasks involved and key events with their exit criteria, to assure that supplier activities support the overall program performance.
- Processes for flowdown of performance specifications and key characteristics.
- Data pertinent to key supplier past performance in areas such as product performance, process performance, manufacturing capabilities, customer satisfaction, and schedule adherence.
- Contractor past performance in the management of supplier schedules and involvement of key suppliers in IPTs.
- Key supplier plans for the implementation of defect prevention processes and techniques.
- Processes for integration of key supplier risk management efforts with the program risk management effort (including cost, schedule, and technical risks).

Key Characteristics

- Detailed description of a design system that includes identification of key product characteristics, identification of key production processes, balancing of key product design requirements to production process capabilities, identification of key process parameters and verification methods.
- The availability of established and validated process control tools and practices.
- Data pertinent to prime contractor and key supplier past performance in key product characteristics and key process parameters identification.

Variability Reduction

- Approaches to variability reduction and plans for implementation
- Planned efforts to document process control plans
- Planned efforts to conduct process capability studies and feed results back to the product design
- Planning for key supplier flowdown of VR methods and requirements.

- Metrics used to manage progress on VR implementation
- Data pertinent to prime contractor and key supplier past performance in variability reduction, product/process matching, and process control.

Long Lead

- The timing of and need for long lead and non-recurring equipment and activities.
- The relationship of ST/STE/SE to key characteristics and key processes.
- The rationale for key events which support the exit criteria.
- ST/STE/SE development in parallel with and as an integral part of development of the prime item.

P&P Validation

- The level of product and process validation effort.
- Simulations and incremental verification and validation processes to proof new tools and processes throughout the development cycle.
- The resources available, the maturity of the products and processes involved, and the level of success of other program events.
- Integration of the line proofing effort into the overall risk management effort.
- Plans for providing guidance on ST/STE/SE validation, and the level of product and process validation effort expected from suppliers.
- Identification of key product and process validation activities in the IMP and in risk management planning.

Production Phase Roll-up - section L

Process Control

- Methods for manufacturing process control and implementation of continuous improvement.
- Procedures for continuous collection and review of data to identify improvement opportunities.
- Configuration control procedures to be employed for product design, ST/STE/SE, production methods and plans, and manufacturing planning.
- Evidence of past performance in the area of process control and continuous improvement.

Key Suppliers

- Approach to identification and selection of any new key suppliers, including key suppliers of GFP, along with criteria used to make the determination.
- Integration of key supplier activities, including suppliers of GFP, into the overall program plan, with descriptions of the tasks involved and events (with their exit criteria) to be tracked to assure that supplier activities support overall program performance.
- Processes for evaluation of key supplier performance, including suppliers of GFP (after appropriate contractual mechanisms for relationships with key suppliers of GFP have been put in place.
- Supplier capabilities or training in the use of defect prevention processes and techniques such as variability reduction.
- Contractor processes and practices for the management of supplier schedules and for involvement of key suppliers in IPTs, including key suppliers of GFP in those cases where the GFP supplier's contract with the Government includes the requirement for the GFP supplier to provide support to the Prime Contractor.
- Integration of risk management efforts at key suppliers with the program risk effort.
- Flow-down of performance specification and key process parameters and key product characteristics.
- Data pertinent to past performance of key suppliers in areas such as product performance, process performance, manufacturing capabilities, customer satisfaction, and schedule adherence.

Variability Reduction

- Planned approach to variability reduction and process control, including flowdown to suppliers.
- Metrics used to manage progress on VR implementation
- Data pertinent to prime contractor and key supplier past performance in variability reduction, and process control, in particular as related to EMD and LRIP results.

Factory Efficiency

- Demonstration of an ongoing production phase commitment to affordability, and a sensitivity to total acquisition costs, capacity constraints, and industrial base issues.
- Sustainment during the production phase of the open environment created by the IPT processes in the preceding phases of the program.
- Direct participation of manufacturing engineering in the decision processes associated with quality metrics, economic trade studies, and make vs. buy decisions.
- Functioning of the Program Office's manufacturing engineering representative as a

member of the IPT, communicating directly with the Program Office with respect to opportunities to improve factory efficiency, contract effectiveness, requirements modifications, schedule changes, and other areas.

Product Improvement

- Processes for managing and controlling design, product, and process configuration.
- A block change plan.
- The Production Cost Modeling process to be used to evaluate product improvements.
- The manufacturing simulation process to be used to evaluate product improvements.
- Prior experience in managing product improvement initiatives in production programs.
- Applicable key supplier processes for managing and controlling design, product, and process configuration.

Manufacturing Capability Assessment

- Production Planning, Control and Management System
- Planned materials and critical manufacturing processes (including purchased or subcontracted items)
- Existing/planned resources
- Manufacturing Management capabilities
- Quality Assurance System, including supplier's Quality Systems
- Other items as needed from "Guidance" section above

Evaluation Criteria Guidance (Section M)

Manufacturing Engineering's Role in IPPD

Evaluation of an offeror's capability to effectively employ IPPD processes should be based upon:

- An established or proposed IPPD process, including team member roles, responsibilities, and authority.
- Previous experience that demonstrates cost and schedule benefits realized by IPPD processes.
- Presentation of a viable plan which can reasonably be expected to effectively institutionalize IPPD in the offeror's organization (if the offeror has no previous IPPD experience).
- Data on existing process cost and capabilities and evidence that the data has been used in design trade studies.
- An established, or proposed, demonstration or analytical approach to validate that the process capabilities needed to achieve the stated affordability requirements are within industry standards or identified as cost and schedule risk issues.

Engineering for Affordability and Producibility

- Established practices for cost requirement allocation and cost flowdown.
- Planned implementation of resources and tools for the consideration of cost requirements in the design trade studies.
- Planned use of formal cost avoidance initiatives/programs such as those described above.
- Planned use of cost risk identification/mitigation processes.
- Plans for flowing down to appropriate suppliers cost avoidance initiatives/programs such as those described above.

Quality Systems

- Establishment of capable processes.
- Monitoring and control of critical processes and product variation.
- Establishment of mechanisms for feedback of field product performance.
- Implementation of an effective root cause analysis and corrective action system.
- Continuous process improvement.

- Ensuring effective management of identified risks.
- Integration of technical and management processes and systems.
- Measurement of the effectiveness of processes and systems.
- Training personnel in the use and deployment of state-of-the-art quality tools and techniques.

Pre-EMD Phase Roll-up - Section M

Production Cost Modeling

- Demonstrated processes for development and accuracy of cost models.
- Demonstrated processes for development of production cost estimates.
- Experience on previous programs related to use and performance of PCMs.

Manufacturing Capability Assessment

- Identification of the databases and processes employed to assess the potential risk of qualifying new materials and proving immature processes.
- Proposed plans for addressing industrial capacity and industrial base sustainment issues.
- Reflection in the program schedule of areas of risk resulting from planned funding sources outside the immediate contract.

Key Suppliers

- Defined criteria for the identification of those suppliers who are key.
- Disciplined, structured processes used for the integration of key supplier events/activities into the IMP and for requirements flow-down.
- Effective performance specification, key process characteristics and key product characteristics flow-down processes.
- Evidence of past performance in the management of supplier schedules and the involvement of key suppliers in IPTs.
- Key supplier experience in (or training plan for) the use of defect prevention processes and techniques.

- Key supplier past performance in cost, schedule, quality, and customer satisfaction areas.
- Data collection and analysis planning.
- Key supplier risk assessment and risk abatement plans (including cost, schedule, and technical risks).

Key Characteristics

- The extent to which a disciplined, structured, and demonstrated process is used for identification of key product characteristics and key processes
- Evidence of prime contractor and supplier past performance in the identification and coordination of key product characteristics and key processes.

Variability Reduction

- The merit of the planned approach to variability reduction.
- The planned utilization of defect prevention techniques and availability of established and validated process control tools and practices.
- Evidence of prime contractor and key supplier past performance in variability reduction, process control, and product / process matching.

Virtual Manufacturing

- Demonstrated ability to manage risk through assembly simulation, process flow simulation, and process capability analysis.
- Demonstrated ability to evaluate manufacturing resource requirements and provide schedule credibility through process flow simulation.
- Contractor experience/past performance related to Virtual Manufacturing.

EMD Phase Roll-up - Section M

Production Cost Modeling

- Robustness of the contractor's processes and procedures for developing and validating a PCM.
- Maturity of the documentation and maintenance practices for configuration control of the PCM.
- Status of the contractor's preliminary model, if available.
- Past performance in developing realistic production cost models for similar systems.

Design Trade Studies

- Established processes for performing and documenting design trade studies and the planned integration of design trade studies and results into the IMP.

- Established process for System Specification requirements allocation and flow down.
- Established processes for addressing the ST/STE/SE requirements as part of the design trade study process
- Past performance of prime contractor and key suppliers in accomplishing design trade studies, with emphasis on such studies performed under the IPT concept.

Manufacturing Capability Assessment

- Identified process capabilities of the prime and key suppliers, with linkage to process requirements.
- Identified Manufacturing Management components such as Production Planning and Control systems, Production Surveillance and Reporting systems, and Subcontractor Management
- Inclusion of Manufacturing Risks. Addressing of supplier capacity and capability constraints and industrial base sustainment issues. Addressing environmental assessments and environmental impacts.

Key Suppliers

- The disciplined, structured, and defined process for identification and selection of key suppliers.
- The process used for evaluation of key supplier performance.
- Effective methodologies for key characteristics and performance specification flowdown.
- Evidence of past performance in the management of supplier schedules and involvement of key suppliers in IPTs.
- Key supplier experience in (or training plan for) the use of continuous improvement and defect prevention processes and techniques.
- Past performance of key suppliers in cost, schedule, quality, and customer satisfaction.

Key Characteristics

- The extent to which a disciplined, structured, and demonstrated process is used for requirements allocation and identification of key product characteristics, key process parameters, and product/process matching.
- The availability of established and validated process control tools and practices.
- Evidence of prime contractor and key supplier past performance in key product characteristics and key process parameters identification.

Variability Reduction

- The understanding of VR principles and their planning for implementation
- Planned efforts to document control plans
- Planned efforts to conduct process capability studies and feed results back to the product design
- Extent to which VR requirements are flowed down to suppliers
- The appropriateness of planned metrics for managing processes
- Evidence of prime contractor and key supplier past performance and capabilities in variability reduction, product/process matching, and process control.

Long Lead

- An LRIP production plan and schedule which address long lead items, ST/STE/SE, and capital requirements to support LRIP activities occurring in EMD.
- LRIP production planning that supports key characteristics and key processes.
- Identification of and planning for long lead items.
- Risk management planning integrated into IMP and IMS.

P&P Validation

- Incremental verification and validation throughout the design process.
- Integration with the risk management plan.
- Use of simulations for verification and validation in virtual environments.
- Demonstrating producibility and production readiness as well as lowered risk and cost through previous experience with simulation and incremental verification and validation.

Production Phase Roll-up - Section M

Process Control

- Demonstrated understanding and use of the concepts of manufacturing process control and continuous improvement of manufacturing processes.
- Disciplined approach to controlling manufacturing processes, continuously seeking and identifying opportunities for improvement, and implementing process improvements.
- Documentation of past experience/performance in this area.

Key Suppliers

- The extent to which a disciplined, structured process is used for the integration of key

supplier events/activities into the IMP.

- Effective practices for key process parameters and key product characteristics flowdown to suppliers.
- The extent to which a disciplined, structured, and defined process is used for evaluation of key supplier performance.
- Evidence of past performance in the management of supplier schedules with emphasis on involvement of key suppliers in IPTs.
- Key supplier experience or training for the use of defect prevention processes and techniques.
- Key supplier past performance in cost, schedule, quality, and customer satisfaction.
- Key supplier risk assessment and risk mitigation planning.

Variability Reduction

- The understanding of VR principles and their planning for implementation
- The appropriateness of planned metrics for managing processes
- Evidence of prime contractor and key supplier past performance in process control and variability management.

Factory Efficiency

- Continued reduction of the AUPP for each procurement.
- Development and use of effective contractor and Program Office metrics in order to monitor effectivity and effectiveness of changes to the product and the production processes, ensuring that product performance is not sacrificed in the continuing effort to improve factory efficiency, or vice versa.
- Maintenance of the basic disciplines of change management, revalidation, and reverification of key characteristics.

Product Improvement

- An established and effective configuration management process as it relates to product improvements.
- A documented Block Change Plan.
- A Production Cost Model developed in EMD and maintained for product improvement during production.
- A production simulation model maintained and used to evaluate potential product improvements.

- The past performance of the prime contractor and key suppliers in initiating and managing product improvements, including related configuration and cost management requirements.

Manufacturing Capability Assessment

- The Production Planning and Control system is evaluated to assure all pertinent parts will be available when needed. If a new process is proposed, its capability may need to be demonstrated.
- Lists of materials and critical processes are examined to insure that all non-routine materials and critical processes are within the capability of the offeror. These processes and process capabilities are verified. The offeror's understanding and control of subcontractors' capabilities is a must.
- Proposed resources are checked against requirements. Planned resources are investigated for availability.
- Manufacturing management's risk management practices are reviewed, and successful relevant risk mitigation actions are viewed as demonstrated capability.
- Evaluate the appropriateness of the proposed Quality System. Emphasize manufacturing process control, defect prevention, and identification and control of Costs of Quality.
- Other items as needed from "Guidance" section above